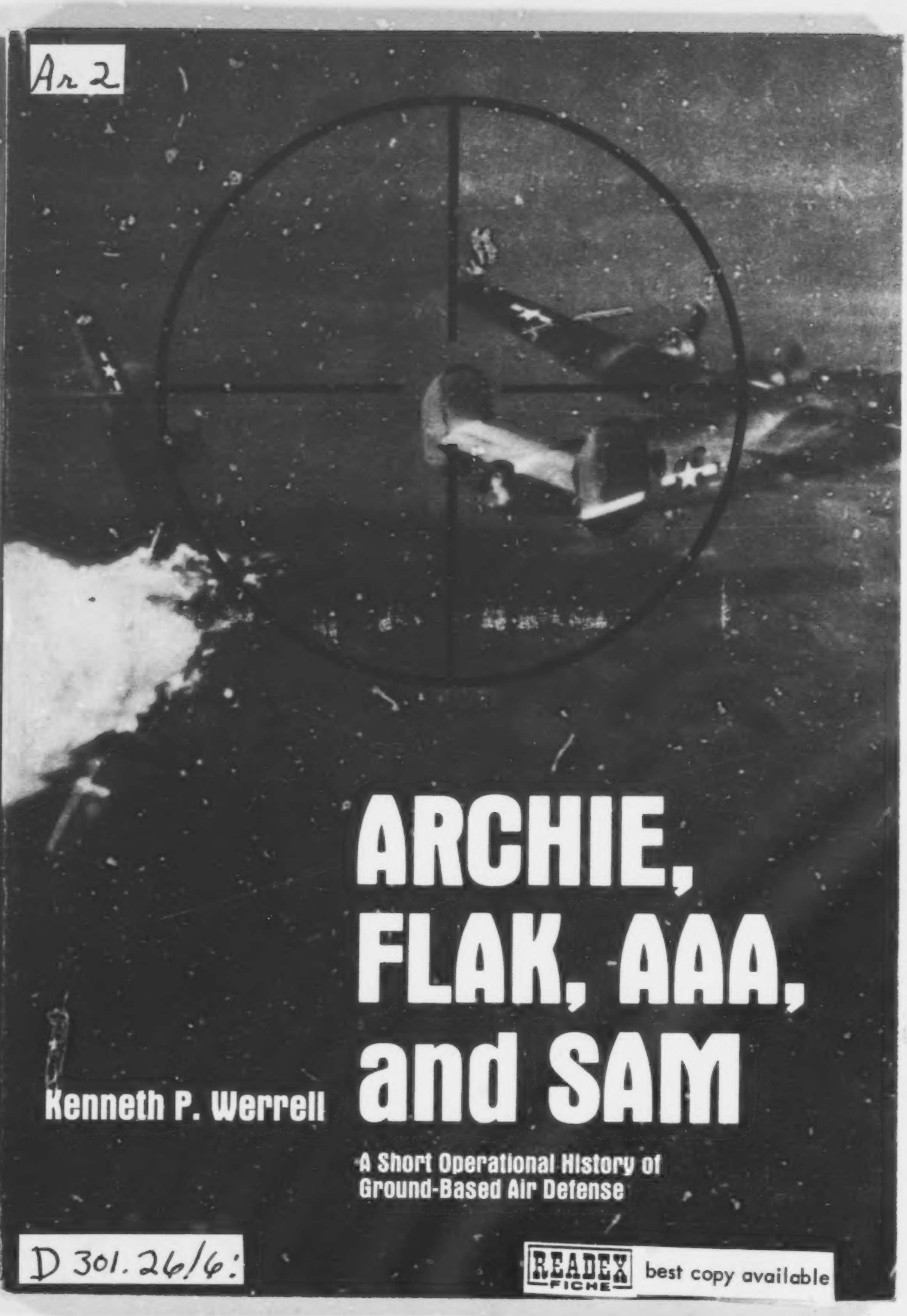
Ar 2



# ARCHIE, FLAK, AAA, and SAM

**Kenneth P. Werrell**

## A Short Operational History of Ground-Based Air Defense

D 301.26/6:

READEX FICHE best copy available

CENTER for AEROSPACE DOCTRINE RESEARCH and EDUCATION

# ARCHIE, FLAK, AAA, AND SAM

## A Short Operational History of Ground-Based Air Defense

*by*

KENNETH P. WERRELL
Senior Research Fellow
Airpower Research Institute

*Air University Press*
*Maxwell Air Force Base, Alabama 36112-5532*

December 1988

**Library of Congress Cataloging-in Publication Data**

Werrell, Kenneth P.
Archie, Flak, AAA, and SAM.

"December 1988."
Includes index.
Bibliography: p.
1. Air defenses, Military—History—20th century. 2. Antiaircraft guns—History—20th century. 3. Antiaircraft missiles—History—20th century. I. Title.
UG730.W47 1988 358.4'145 88-7596

## DISCLAIMER

This publication was produced in the Department of Defense school environment in the interest of academic freedom and the advancement of national defense-related concepts. The views expressed in this publication are those of the author and do not reflect the official policy or position of the Department of Defense or the United States government.

This publication has been reviewed by security and policy review authorities and is cleared for public release.

---

For Sale by the Superintendent of Documents
US Government Printing Office
Washington, DC 20402

Michael Lewis Hyde
Born: 14 May 1938
Graduated USAF Academy: 8 June 1960
Killed in Action: 8 December 1966
A Patriot, A Classmate, A Friend

## *CONTENTS*

*Chapter* *Page*

DISCLAIMER ii

FOREWORD xi

ABOUT THE AUTHOR xiii

PREFACE xv

ACKNOWLEDGMENTS xix

1 THE EARLY YEARS TO 1945 1
- British Antiaircraft Artillery 4
- The V-1 Campaign 10
- American Antiaircraft Artillery 21
- German Flak Defenses 23
- Allied Countermeasures 43
- Fratricide 46
- The US Navy in the Pacific 51
- Japanese Antiaircraft Artillery 53
- The Lessons of World War II 57
- Notes 59

2 THE POSTWAR YEARS, 1945–65 71
- The Korean War 73
- Antiaircraft Missiles 82
- Notes 91

3 VIETNAM 95
- French Operations 95
- American Operations through 1968 96
- American Operations through Linebacker I 112
- Linebacker II 119
- Conclusions 126
- Notes 127

4 RECENT EXPERIENCE 137
- Arab-Israeli Wars 137
  - 1948, 1956, and 1967 137

*Chapter* *Page*

1967–73 ........ 138
1973 ........ 139
1982 ........ 146
American Air Strikes in the Middle East, 1983–86 ........ 147
Indian-Pakistani Wars ........ 150
The Falklands, 1982 ........ 151
Ongoing and Recent Aspects ........ 162
Summary ........ 167
Notes ........ 168

5 SUMMARY, TRENDS, AND CONCLUSIONS ........ 177
Summary ........ 177
Trends (Speculations) ........ 181
Conclusions ........ 182

INDEX ........ 185

## ILLUSTRATIONS

*Figure*

1 German 7.7-cm antiaircraft gun, 1916 ........ 2

2 Improvised antiaircraft weapons ........ 3

3 Antiaircraft battery training ........ 4

4 British women receiving antiaircraft training ........ 7

5 British experimenting with rockets during World War II ........ 8

6 British 40-mm gun and crew ........ 9

7 V-1 buzz bomb over London ........ 11

8 Initial British defensive deployment ........ 12

9 Preparing Pile mattress ........ 14

*Figure* *Page*

10 3.7-inch gun mounted on a Pile mattress .......... 15

11 Final British defensive deployment .................... 16

12 Defense of Antwerp, Belgium ............................ 20

13 US 90-mm M-1 AAA gun .................................. 21

14 German 88-mm gun ........................................... 25

15 German 88-mm gun was versatile ...................... 26

16 88-mm gun on the march .................................. 27

17 German 128-mm gun ......................................... 28

18 Ploesti mission was dramatic and costly ........... 30

19 German radar in Romania ................................. 31

20 Ploesti was protected by smoke and guns ......... 32

21 German light flak was very effective ................ 33

22 German 20-mm guns aboard train .................... 34

23 German light flak pieces mounted on motor vehicles ............................................................ 35

24 40-mm Bofors on truck chassis .......................... 35

25 50-mm gun on five-ton towing vehicle ............. 36

26 128-mm railway guns were largest in Ploesti .... 36

27 German Taifun rocket ........................................ 38

28 Enzian rocket ...................................................... 39

29 Rheintochter rocket ........................................... 40

30 German Schmetterling ....................................... 41

31 Wasserfall ........................................................... 42

*Figure* *Page*

32 Chaff ........ 44

33 Liberator over Italy ........ 47

34 B-17 nose shot away by flak over Cologne ........ 48

35 German flak was impressive ........ 48

36 Douglas A-20s attack Japanese positions at Karos ........ 55

37 B-29 hit by Japanese flak on bombing run ........ 56

38 75-mm Sky Sweeper ........ 73

39 F-51 Mustang fighters at air base in Korea ........ 75

40 F-80 Shooting Star jets destined for Communist transportation targets ........ 76

41 B-26 light bombers ........ 77

42 C-119s ........ 79

43 T-6 ........ 81

44 Nike Ajax ........ 83

45 Nike Hercules ........ 84

46 Hawk ........ 85

47 Redeye ........ 86

48 Talos missile ........ 88

49 Tartar missile ........ 88

50 Boeing IM-99 Bomarc guided missile ........ 90

51 Bomarc interceptor missile ........ 91

52 American adviser instructing South Vietnamese troops ........ 97

| *Figure* | | *Page* |
|---|---|---|
| 53 | C-123K delivers needed supplies | 98 |
| 54 | North Vietnamese scramble for their guns | 98 |
| 55 | A-6A Intruder attack aircraft over the Gulf of Tonkin | 100 |
| 56 | F-105 Thunderchief pilots head for North Vietnam target | 101 |
| 57 | Phantom attacks | 103 |
| 58 | RF-4C reconnaissance aircraft | 104 |
| 59 | Abandoned surface-to-air missile site in North Vietnam | 104 |
| 60 | North Vietnamese SA-2 position | 105 |
| 61 | Soviet SA-2 | 106 |
| 62 | SA-2 launch against US aircraft | 106 |
| 63 | EB-66 | 109 |
| 64 | A-4 Skyhawk aircraft fires Shrike missile | 110 |
| 65 | F-105G Wild Weasel on the wing of a tanker | 111 |
| 66 | CH-53 helicopter | 113 |
| 67 | VNAF Choctaws | 114 |
| 68 | Regional forces scramble out of an H-34 | 114 |
| 69 | Soviet SA-7 Grail surface-to-air missile | 115 |
| 70 | AQM-34V in flight with an AN/ALE-38 chaff pod | 118 |
| 71 | Marine EA-6B Prowler aircraft | 119 |
| 72 | B-52 dropping bombs | 120 |

*Figure* *Page*

73 B-52 aircraft damaged by SAM missile ............ 121

74 Standard arm missile (AGM-78) igniting ......... 124

75 Soviet SA-6 ........................................................ 141

76 Soviet ZSU-23-4 ................................................. 142

77 Soviet SA-9 ......................................................... 148

78 Canberra ............................................................ 152

79 Avro Vulcan ....................................................... 152

80 Hawker Siddeley Harrier ................................... 153

81 Blowpipe launcher ashore on the Falkland Islands ................................................................ 156

82 Stinger ................................................................ 157

83 Rapier surface-to-air antiaircraft missile .......... 158

84 Rapier system under a camouflage net ............. 158

85 7.62-mm GPMG deployed ashore on Falklands ........................................................... 159

86 Seacat ................................................................. 160

87 British antiaircraft weapons .............................. 161

88 Bofors antiaircraft gun served in the Falklands ........................................................... 162

89 Seaslug ............................................................... 163

90 Sea Dart launch during peacetime .................... 164

91 Afghanistan rebels down Soviet helicopter ........ 165

# *FOREWORD*

Dr Kenneth Werrell's history of ground-based air defense performs an important service both to scholarship and, more important, to the defense of our nation's freedom. It is perhaps human nature that we tend over time to lose sight of the lessons of the past, especially when they do not conform to certain cherished preconceptions of ours. That such myopia can be dangerous, if not downright disastrous, Doctor Werrell's study richly illustrates. Without sentimentalism, he chronicles a pattern of lessons learned and too quickly forgotten, as the marvel of air power was reminded again and again of its limitations and vulnerability. In Korea and in Vietnam, the American people were stripped of their illusions of national and technical omnipotence. The unhappy outcome of those two conflicts were doubly lamentable because the lessons of World War II were—or should have been—fresh in our minds. In that world war, as Doctor Werrell shows, relatively cheap ground-based air defense did make a difference: at Ploesti, at Antwerp, and at the Rhine bridges.

And it will make a difference tomorrow. The greatest value of Doctor Werrell's work is that it provides guideposts and guidance for us as professional soldiers and aviators charged with upholding American security. We have taken history's lessons to heart as we plan and program our ground-based air defenses into the next decade and beyond. In both the forward and the rear areas, we have emphasized the time-honored principles of mass, mix, and mobility. No one weapon, not even today's modern aircraft, can do the job alone. That truism applies with particular force to antiaircraft defense. And at least one other truism emerges from Doctor Werrell's and our own studies: effective air defense requires a joint and combined effort. Our planning has been predicated on the assumption that counterair will play a central role in safeguarding our ground forces from air attack. On the ground, the Air Defense Artillery will count on the cooperation and assistance of our colleagues in the infantry, armor, and field artillery. On our success or failure in working together to meet the challenges of tomorrow will rest our nation's future.

Donald R Infante
DONALD R. INFANTE
Major General, US Army
Chief of Air Defense Artillery

# ABOUT THE AUTHOR

Dr Kenneth P. Werrell conducted this study while serving as a visiting professor at the Air University Center for Aerospace Doctrine, Research, and Education (AUCADRE), Maxwell AFB, Alabama.

A graduate of the United States Air Force Academy, Doctor Werrell holds master and doctorate degrees from Duke University.

Doctor Werrell was commissioned upon graduation from the United States Air Force Academy in 1960 and received his pilot wings in 1961. Assigned to the 56th Weather Reconnaissance Squadron in Yokota, Japan, from 1962 until 1965, Doctor Werrell served first as a pilot and later as aircraft commander of the WB-50. He resigned his commission with the rank of captain in 1965.

Doctor Werrell is professor of History at Radford University, Virginia. His background includes a visiting associate professor assignment at Command and General Staff College and historian assignments for both Operations Research, Inc., and the War Department Historical Fund.

A frequent participant in military history workshops and conferences, Doctor Werrell has authored several articles and two books on military history: *Eighth Air Force Bibliography* (Manhattan, Kans.: Aerospace Historian, Kansas State University, 1981), and *The Evolution of the Cruise Missile* (Maxwell AFB, Ala.: Air University Press, September 1985).

# *PREFACE*

*Archie, Flak, AAA, and SAM* is an operational history of ground-based air defense systems from the beginning of air warfare up through 1988. The title refers to the name that airmen use, and have used, to describe ground fire: Archie in World War I (from the British), flak in World War II and Korea (from the Germans), AAA throughout, but especially in Vietnam (from the American abbreviation for antiaircraft artillery), and most recently SAMs (from the US abbreviation for surface-to-air missiles). This study concentrates on how these weapons developed and how they impacted on both US and non-US air operations.

The subject of ground-based air defense systems is neglected for a number of reasons. First of all, research is difficult because source material is fragmented. Even more significant is the fact that the topic does not have "sex appeal." Readers are more interested in the aircraft than the weapons that bring them down. Whereas the airplane appears as a dynamic, advanced, exciting, and offensive weapon, ground-based air defense systems are seen in the opposite light. Further, US experience has been almost exclusively with the offensive use of aircraft, not with the defensive use of flak and SAMs; Americans have seldom fought without air superiority. Too, there is the World War II example that many, if not most, people hold as the archetypical war—during which aircraft defeated all comers on all fronts. Another factor is that the air defense community has been overwhelmed by the air offensive community. Not that the former is any less able or less professional than the latter, only that the air offensive community has the attention and support of both industry and Congress. Little wonder then that the subject of flak and SAMs has been neglected.

Despite this neglect and the aforementioned reasons, ground-based air defense systems are important. They have been involved and have impacted on most air conflicts and have achieved notable successes in some. These weapons have downed and damaged large numbers of aircraft and consequently have forced aviators to make changes and pay higher costs for operations. Clearly ground-based air defenses have been ever present and have always been a factor in air wars. There is no indication that this influence will diminish in the future.

The neglect of the subject of ground-based air defense systems on the one hand, contrasted with its importance on the other, prompted this study. In it, I have traced the historical record from World War I up through a number of smaller conflicts in the 1980s. Although primarily a narrative, I have tried to analyze the story and draw from it some generalizations, however tentative they may be. I prefer "generalizations" to the often misused term "lessons."

The acknowledgments indicate where I conducted my research and the footnotes document the material upon which I based this study. Research was overwhelmingly confined to English language sources, the basis of which was US Air Force, Army, and Navy documents and studies. In addition, I found primary materials dealing with both the Royal Air Force and Luftwaffe. I made considerable use of secondary sources, and I employed a few interviews. Admittedly, the major difficulty of this study is that, while I found materials from both sides covering the World Wars and to a lesser extent some of the more recent smaller wars, my coverage of the Korean, Vietnam, and Middle East Wars is drawn primarily from one side. Finally, I did not use the rich, although spotty, classified materials for obvious reasons.

Without preempting the conclusions, a number of themes are present. A study of the evolution of ground-based air defense weapons provides a classic view of the perennial contest between offense and defense, as well as of the impact of technology on warfare. More than just technology is involved, however; coverage includes such topics as tactics, leadership, change, and innovation. Perhaps most important, this subject cannot be even casually studied without the distinct impression that many of the main features of aircraft versus ground-based air defense battles are repeated over and over again. Clearly, lessons and generalizations abound in this story. I trust my treatment will do justice to the topic; that is, I hope that the result makes up for some of the previous neglect of this subject and is commensurate with its past and continuing importance.

Kenneth P. Werrell
KENNETH P. WERRELL
Senior Research Fellow
Airpower Research Institute

# *ACKNOWLEDGMENTS*

Many individuals and organizations helped make this book possible. First, I wish to thank those at my home institution, Radford University, who encouraged and made possible my work with the Air University: the Board of Visitors; Dr Donald Dedmon, president; Dr David Moore, vice president for Academic Affairs; Dr W. D. Stump, dean of the School of Arts and Sciences; and Dr W. K. Roberts, chairman of the Department of History. Lt Gen Charles Cleveland, former commander of the Air University; Maj Gen David Gray (USAF, Retired); and Maj Gen Paul Hodges, former commandant of the Air War College, were unsparing in their support throughout this project. Col Thomas Fabyanic (USAF, Retired), the founder and first director of the Airpower Research Institute (ARI), and Col Kenneth Alnwick (USAF, Retired), his successor, deserve much of the credit for helping conceive the concept, encourage the project, and remove many of the barriers encountered. Also, special thanks to Col Neil Jones (USAF, Retired) who provided photos for this book. Later CADRE commanders Col Donald D. Stevens (USAF, Retired), Brig Gen John C. Fryer, Jr., and Col Sidney J. Wise provided vital publication assistance. Others at the Air University helped in many important ways, especially Col Dennis Drew, Preston Bryant, Dianne Parrish, John Westcott, and Dorothy McCluskie. Many individuals helped in document processing: Lula Barnes, Sue Carr, Carolyn Ward, Marcia Williams, and Cynthia Hall. For logistical support I am thankful to Capt Harbert Jones, Betty Brown, and Marilyn Tyus. The US Air Force History Program helped in a number of ways. These individuals include Dr Richard Morse, Lynn Gamma, Judy Endicott, Pressley Bickerstaff, and Margaret Claiborn of the US Air Force Historical Research Center. The Air University Library played a key role in making this book possible, with special thanks due Tomma Pastorett, Ruth Griffin, and Kathleen Golson. The US Army also lent considerable support to this project. Especially helpful were the officers and staff at Fort Bliss: Air Defense School, Air Defense Museum, and Directorate of Combat Development. Special thanks are due Jesse Stiller, the Air Defense Artillery Command Historian. Overseas, Air Commodore H. A. Probert, Humphrey Wynn, and J. P. McDonald, at the Air Historical Branch, London; the staff at the Royal Artillery Institute, Woolwick, United Kingdom; and E. Hines and Paul J. Kemp of the Imperial War Museum, London, made research of the British and German side of the story possible.

Finally, I must thank my entire family, especially my wife Jeanne, who endured much to make this project possible.

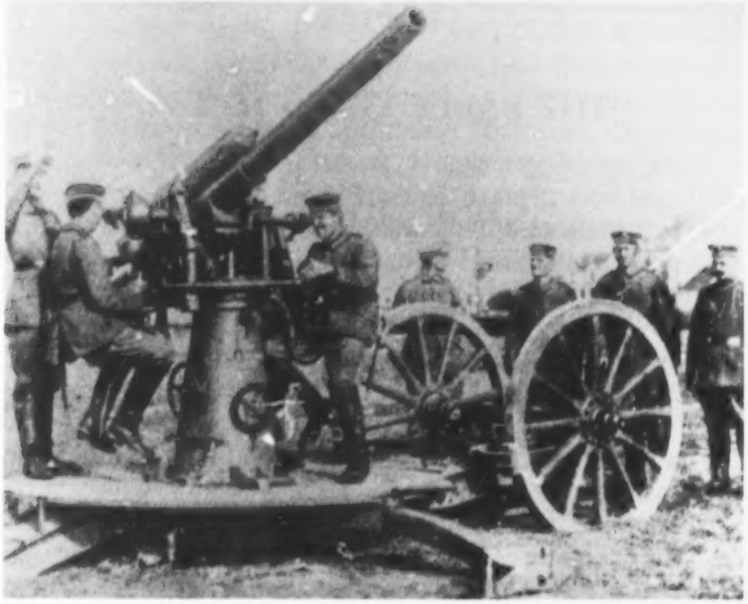
## CHAPTER 1

# THE EARLY YEARS TO 1945

The genesis of antiaircraft defense appeared soon after man took to the air. There are reports of balloon and antiballoon artillery in the American Civil War and the Franco-Prussian War, and in 1890 the Russians tested a field-gun battery against a balloon moored three kilometers away. The first aircraft downed in combat fell to ground fire in the Italo-Turkish War of 1912; so when World War I began, there were precedents for ground-based air defense systems.

During the war, both sides bombed their opponent's cities. The bombing of London and Paris by the Germans tied down considerable Allied resources, estimated in the British case to be eight times the resources expended by the Germans. British defenses claimed 21 airships (of 201 airship sorties) and 27 aircraft (of 424 aircraft sorties), of which ground fire accounted for three Zeppelins and 11 to 13 aircraft. In November 1918 the British used 480 antiaircraft guns and 376 aircraft in the defense of Great Britain.[1]

Nevertheless, aircraft flew primarily in support of ground forces. On the Western Front, German antiaircraft gunners (fig. 1) claimed 1,588 Allied aircraft, while French gunners claimed 500 German aircraft; Italian gunners claimed 129; British Expeditionary Force gunners, 341; and US gunners, 58. The guns grew increasingly effective as hastily improvised equipment gave way to specially designed equipment, while, relatively speaking, aircraft showed only modest improvements in performance (fig. 2). The number of German antiaircraft rounds for each claim fell from 11,588 in 1915 to 5,040 in 1918. Similarly, French rounds per claim decreased from 11,000 in 1916 to 7,000 in 1918, and British

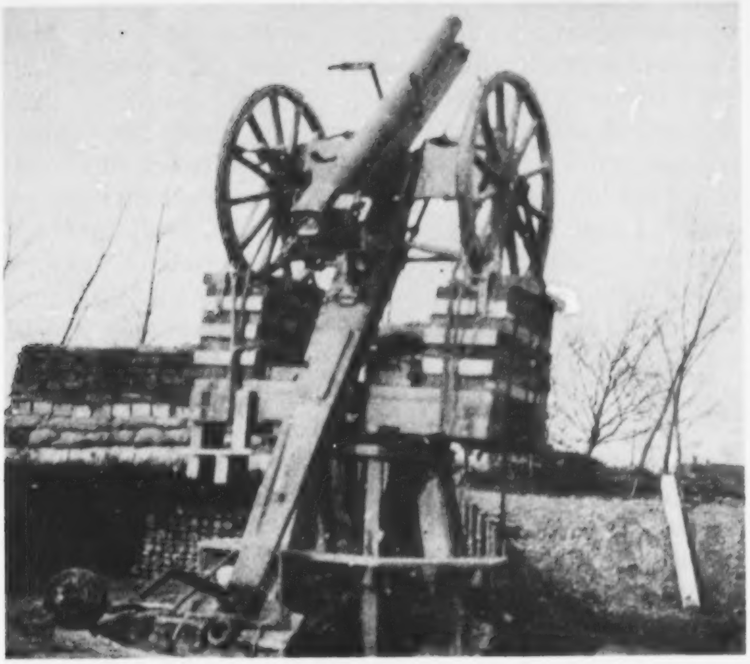


*(Photo Credit: USAF Historical Research Center)*

**Figure 1. German 7.7-cm antiaircraft gun, 1916.**

rounds per claim fell from 8,000 in 1917 to 4,550 in 1918. American antiaircraft artillery downed 17 German aircraft in three months, averaging 605 rounds per kill.[2]

In contrast to World War I, the air defenders made little progress between the wars. The three-inch gun of World War I dominated what little antiaircraft artillery there was, and acoustical devices provided the best location equipment. In 1928 the United States adopted as standard equipment the three-inch M3 gun with a muzzle velocity of 2,600 to 2,800 feet per second (fps) (fig. 3). It had an effective ceiling of 21,000 feet, just exceeding the 17,000-foot aircraft ceiling of the day. Meanwhile, new technology—such as removable barrel liners, automatic breech mechanisms, and



(Photo Credit: Imperial War Museum)

**Figure 2. During World War I many of the antiaircraft weapons were improvised.**

continuous fuze setters—improved the antiaircraft guns. But the revolution in aviation technology of the 1930s, permitting much greater aircraft speeds and altitudes, rendered three-inch guns and acoustical-location gear obsolete.

In the latter half of the 1930s, new equipment began to appear in antiaircraft units around the world. The major powers adopted slightly larger but much more powerful guns, settling on about a 90-millimeter (mm) gun with a muzzle velocity of 850 to 900 meters per second and a rate of fire of 30 rounds per minute (rpm). The Germans chose the 88-mm triple-purpose gun, the British built a prototype

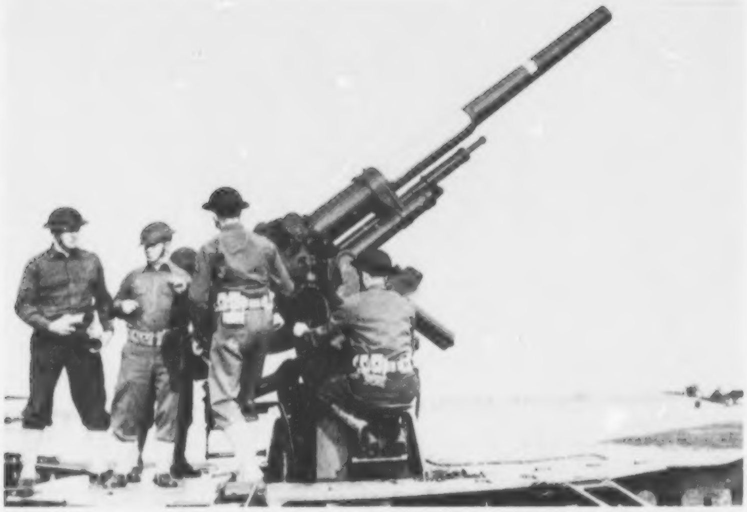


**Figure 3.** **Three-inch antiaircraft battery of the 62d Coast Artillery trained at approaching plane of the 33d Pursuit Squadron, Mitchel Field, New York, August 1941.**

3.7-inch gun in 1936, and the Americans began to replace their three-inch gun with a 90-mm gun in 1940. All major powers experimented with new detection devices, but it was the British who forged a lead in the field of radar.[3]

## British Antiaircraft Artillery

The British had the most acute air defense problem. Of all the European capitals, London was easiest to find and closest to the border. In Winston Churchill's colorful words, the British capital was "a tremendous fat cow . . . tied up to attract the beasts of prey."[4] The British convinced themselves of the decisiveness of air power, fearing what they called the "knockout blow." They accepted the dismal prophecies of theorists such as the Italian Giulio Douhet, the Briton Sir Hugh Trenchard, and the American William "Billy" Mitchell who predicted that the employment of air power would result in devastated cities, pulverized industries, and panic-stricken civilians. These airmen believed that there was no direct defense against the bombers and that, in Prime Minister Stanley Baldwin's words, "the bomber will always get through." Therefore, the British put their faith and effort into a strategic bomber force, neglecting most defensive air efforts. Not until 1937 did the Royal Air Force (RAF) shift its emphasis from bombers to fighters. On 1 January 1938 the British had only 180 antiaircraft guns larger than 50 mm. This number slowly increased to 341 by September 1938 (Munich), to 540 in September 1939 (declaration of war), and to 1,140 during the Battle of Britain.[5]

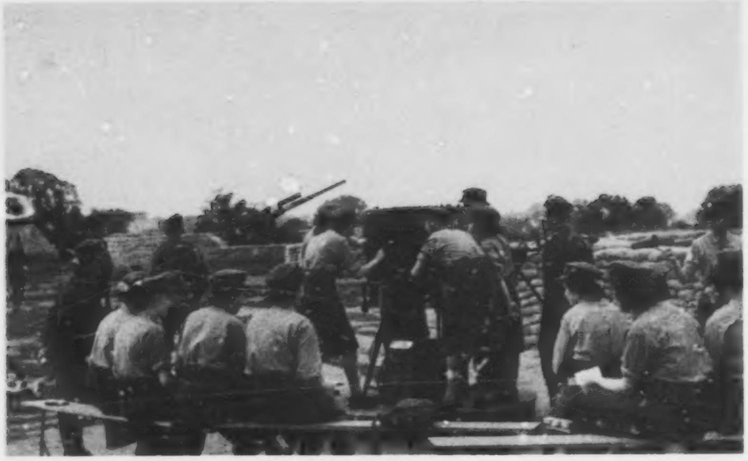
During the decisive Battle of Britain, antiaircraft artillery played a secondary role to RAF fighters. The gunners claimed 357 of the 1,733 German aircraft the British believed they destroyed, even though a more recent source puts the gunners' scores at less than 300. But the measure of efficiency must include more than simply claims. By the end of September 1940, the British estimated that 48 percent of the German bombers turned back from the defended areas. Even if that is an overestimation, flak unquestionably forced the bombers higher, unnerved the crews, and resulted in reduced bombing accuracy. In addition, antiaircraft guns were the principal defense weapon against night attacks as night fighters were in their infancy. By the end of 1940 antiaircraft artillery defenses claimed 85 percent of the British night kills.

British antiaircraft artillery defenses had a number of problems, for example, their first kill—three days after the declaration of war—was unfortunately a friendly aircraft that had even given the correct recognition signal. (The first German aircraft claimed by antiaircraft artillery did not come until over a month later, on 19 October 1939.) The defenses consisted of a mixture of older three-inch guns, which the British employed until 1943, and the new 3.7-inch guns. Sighting was visual until October 1940, when the British began to equip their forces with gun-laying radar. Radar made a big difference—the number of rounds fired per claim at night fell from 30,000 in September (when German night bombing began), to 11,000 in October, and to 4,087 in January 1941.[6]

A problem that hampered British antiaircraft defenses throughout the war was that of personnel. The British sent their regular antiaircraft units overseas and relied on territorial forces, similar to the American National Guard, for home defense. At the beginning of the war, the territorial forces were of top quality. But as the war continued, experienced men were reassigned to other duties, and the overall quality of the forces declined. The first group of 25 militiamen to arrive at one battery, after passing through a medical examination at a recruiting center, included two individuals with advanced cases of venereal disease, one person with a withered right arm, one mentally deficient, one with no thumbs, and a sixth whose glass eye fell out when he ran.[7]

The drain on antiaircraft personnel forced the British to take drastic measures—they incorporated women into what they called mixed batteries. The first such unit became operational in August 1941; in it women filled all positions except those involving heavy loading and firing. The women served well in many capacities, the principal problems resulting not from them but from their parents, friends, and British culture. In all, about 68,000 women served in British antiaircraft units during the war (fig. 4).

Another approach to the manpower shortage was to use the Home Guard. These men were, for the most part, willing enough but were either over age or physically restricted. In addition, they could only serve 48 hours every 28 days. The peak strength of the Home Guard serving guns exceeded 145,000 in January 1944. One antiaircraft weapon employed by the Home Guard early in October 1941 was



*(Photo Credit: Imperial War Museum)*

**Figure 4. British women training on antiaircraft gun director.**

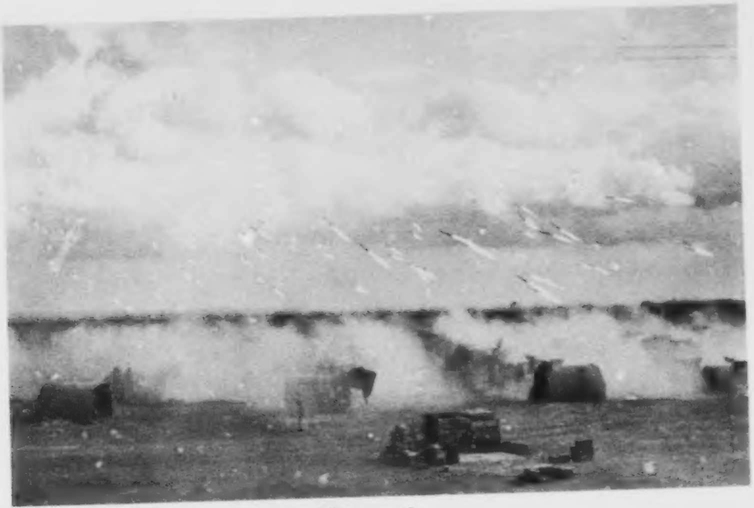
the terrifying but ineffective unguided rocket (fig. 5).* Despite these measures to compensate for shortages in manpower, the number of personnel assigned to antiaircraft duties declined from 330,000 in 1941 to 264,000 in mid-1942. Britain just did not have sufficient personnel for all its needs, and the number of personnel available for antiaircraft duties determined how many guns the British could operate.[8]

The Germans also faced stiff opposition from Allied antiaircraft artillery on the battlefield. Initially, mobile warfare and an inadequate number of guns reduced the effectiveness of Allied flak; but after the first few years of the war, especially in static positions, the situation changed to the detriment of the German air force (GAF).

At the siege of Tobruk, for example, the Luftwaffe made

---

*In July 1941 the British deployed 1,000 rocket barrels. Almost 6,000 were deployed by July 1943, most of which were twin-barrel devices. But rocket units registered few claims.

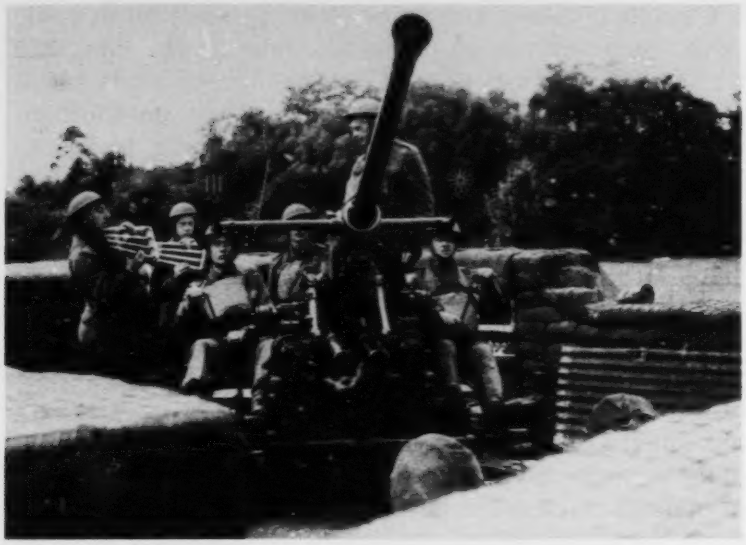


(Photo Credit: Imperial War Museum)

Figure 5. The British experimented with rockets during World War II.

a determined effort to silence British antiaircraft guns and shut down the harbor. From April 1941 (when the garrison was cut off) until November 1941 (when it was relieved), British flak units engaged 4,105 aircraft with 28 heavy guns, 18 40-mm Bofors (fig. 6), and 42 captured Italian 20-mm Bredas. The gunners claimed 374 aircraft destroyed, probably destroyed, and damaged. More important, the Germans sank only seven ships during the siege and failed to close the harbor.

In 1941 the vital British defense facilities on Malta came under aerial siege. The island, only 60 miles from Sicily, was critical in the battle for the Mediterranean and North Africa. In early 1942 the German air force won air superiority over Malta and pounded it ferociously. For two months the British antiaircraft gunners defended Malta alone. The critical month was April when Axis airmen flew 10,323 sorties and dropped about 7,000 tons of bombs,



***(Photo Credit: Imperial War Museum)***

**Figure 6. British 40-mm gun and crew. The Swedish Bofors 40-mm saw extensive action throughout the world, serving both sides.**

about half the total tonnage unloaded on the island. The British claimed 102 aircraft destroyed that month; however, the correct figure is probably closer to 37. During the entire campaign the defenders (airmen and gunners) claimed between 860 and 1,000 aircraft destroyed on 1,199 air raids, while the Axis admit to the loss of 567. Whatever the actual number, the stout and successful defense of Malta contributed immensely to the Axis defeat in North Africa.[9]

Developments in technology aided the defenders. By 1943 the British converted from powder to mechanical fuzes. Flashless propellants also increased the efficiency of their guns, as did automatic fuze setters that improved accuracy and increased the rate of fire two and one-half to three times. By this time, electric predictors were also used.[10]

German bombing attacks on Britain trailed off in 1941, as the Soviet campaign began to dominate the European war. On 27 March 1942 the Germans opened a new phase in the air war against Britain with attacks on southern coastal towns by small numbers of low-flying fighter-bombers. A lack of early warning devices, a wide range of targets, and an inadequate number of light antiaircraft guns created problems for the defenders. The British could do nothing about the first two factors, but they did increase the number of 40-mm guns from 43 in May 1942 to 267 by the end of September. By April 1943 the British had deployed 917 40-mm guns, 424 20-mm guns, and 506 two-pounders (one-third of their available 40 mms and two-fifths of their light flak units) along the southern coast. The increased alertness of the gunners and increased number of guns brought about impressive results. The gunners downed four of 42 sorties on 23 May, four of 24 sorties on 25 May, and 10 of 35 sorties on 30 May. In this phase of the air war—hit-and-run attacks on fringe targets—the British claimed 56 aircraft destroyed of 1,250 sorties, an attrition rate of 4.5 percent.[11]

## The V-1 Campaign

The last major opponent of British home-based antiaircraft artillery was the German V-1 (fig. 7), the flying bomb also known as the buzz bomb, which carried a two-ton warhead about 160 miles at approximately 400 miles per hour (mph). Allied defenses consisted of offensive bombing raids of V-1 targets (launching sites, fabrication plants, and supply depots), fighter patrols, balloon barrages, and antiaircraft artillery. Initially, the defenders assumed that the pilotless bomb would fly at about 400 mph and at a height of 7,500 feet. Later, they revised their assumptions to 350 mph at 7,000 feet and, finally, to 330 mph at 6,000 feet. The British completed a detailed plan on the defense of

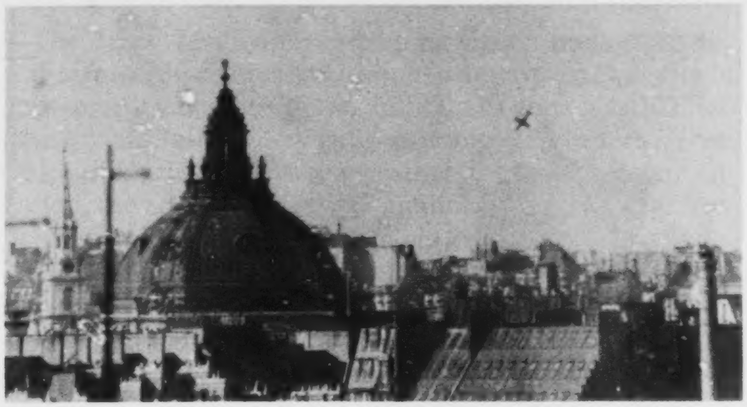


Figure 7. V-1 buzz bomb over London.

their homeland in January 1944. The plan established fighter patrol lines and an artillery line of 400 heavy pieces and 346 light pieces immediately south of London (fig. 8). But the demands of supporting the D-day invasion and optimism resulting from the bombing of the German launch sites led to a revision in March. The revised plan called for a reduction in the number of guns defending London to 192 heavy pieces and 246 light pieces, and a total reduction from 528 to 288 heavy pieces and from 804 to 282 light pieces. Air Chief Marshal Roderic Hill, the defense commander, pointed out that the antiaircraft artillery would have difficulties if the V-1s operated at 2,000 to 3,000 feet and not at the predicted 6,000 feet.[12] Events validated Hill's warning.

After the Allied invasion of Europe on 6 June 1944, Adolph Hitler pushed for the V-1 campaign as a means of relief for his troops. The Germans hoped to begin operations on 11 June, but they were forced to postpone operations until the next night. Even then, they could fire only two small salvos; but by 18 June the Germans launched the 500th V-1, by 21 June the 1,000th, by 29 June the 2,000th, and by 22 July the 5,000th. These V-1 attacks continued

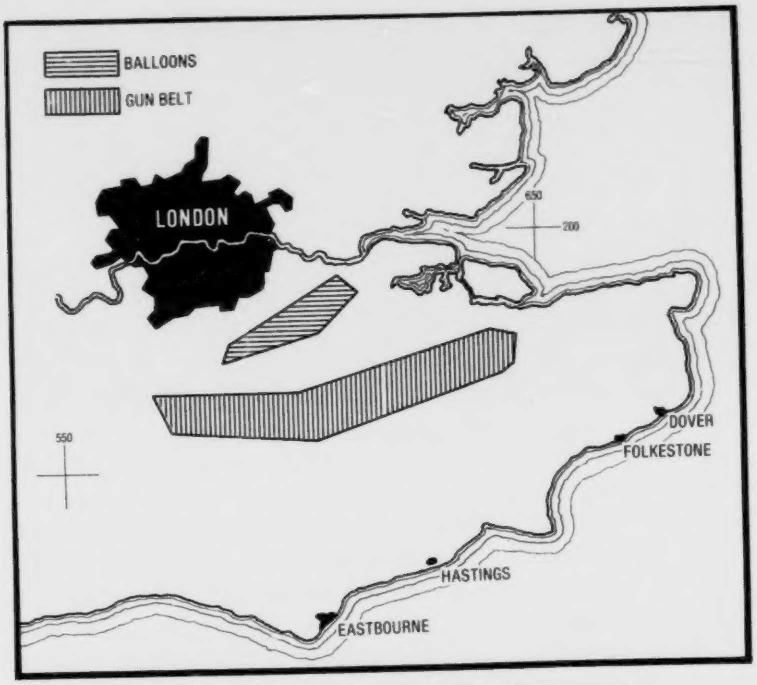


**Figure 8. Initial British defensive deployment.**

until September, when the Germans withdrew from their French bases before the Allied advance.[13]

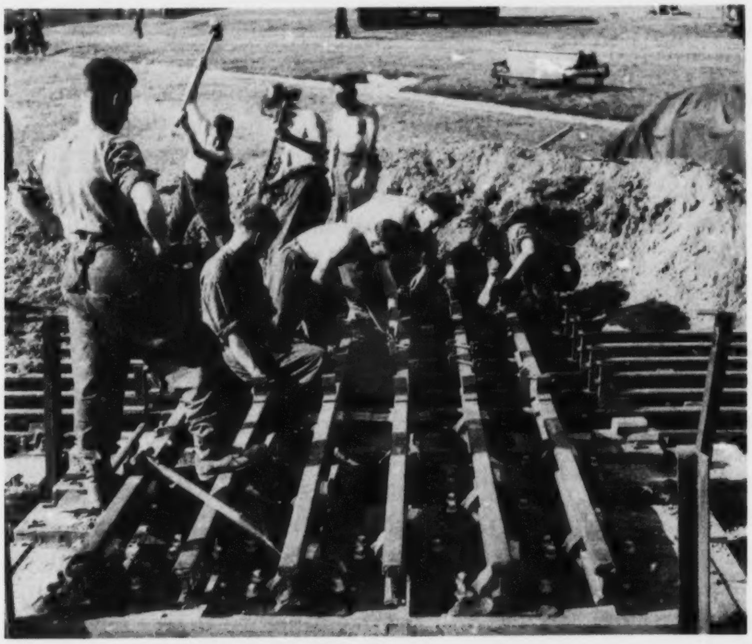
The V-1s traveled fast for the day, crossing the English coast at an average speed of 340 mph and accelerating to about 400 mph. Thus the fighters had but six minutes to sight and down the V-1s before they reached their target. Because of their small size, the V-1s were difficult to spot. This problem was exacerbated by the low-altitude approach averaging between 2,100 and 2,500 feet. Not only was the V-1 tough to spot and intercept, it was also tough to down. One source estimated that a V-1 was eight times as difficult to down as a manned aircraft, even though it flew straight and level. That estimate was probably an exaggeration, but the V-1 was certainly a difficult target to destroy.[14]

The Allies steadily increased their fighter units to 15 day and eight night fighter squadrons (two part-time). Rules of engagement gave the fighters full rein in good weather and gave antiaircraft artillery gunners complete freedom in bad weather. During in-between weather, the most frequent situation, the antiaircraft artillery gunners had complete freedom up to 8,000 feet. On 10 July the British modified a 26 June order allowing fighters to enter the gun belt in hot pursuit of V-1s. Consequently, fighter pilots entered active antiaircraft gun areas at their own risk.[15]

England's third line of defense, after the offensive bombing and the fighter patrols, was its antiaircraft artillery. When the campaign began, the Allies rapidly got 192 heavy guns into position with the support of 200 light guns; and by the end of June, increased this number to 376 heavy guns, 594 light guns, and 362 rocket launchers.[16] But despite these numbers, V-1s were getting through as British defenses were not working at optimum efficiency. The V-1's operating altitude of 2,000 to 3,000 feet was the worst-possible altitude for the defense—too high for the light guns and too low for the heavy guns. Heavy mobile pieces proved unsatisfactory because they could not traverse smoothly and rapidly. Radar, positioned in hollows and folds in the terrain to protect it from German countermeasures that did not materialize, operated at a disadvantage. The proximity of the gun belt to London created another problem. The British hit a number of V-1s that later crashed into London, even though the defenders had done their job. Finally, there was considerable interference between the gunners and the fighter pilots—fighters chasing the fast, low-flying missiles sometimes strayed into the gun belt, inhibiting the gunners who sometimes fired on the fighters as well as the missiles. The defenders made a fast, effective, and flexible adjustment to the situation, which was much to their credit and to a large degree responsible for their ultimate success.[17]

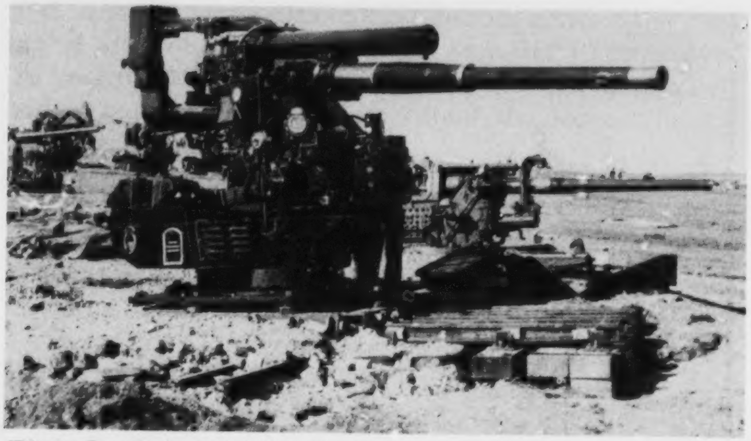
The defenders easily came to grips with some of the problems—on 18 June 1944 they ordered guns within London silenced and by the end of June resited their radar onto higher ground. The defenders built permanent structures for their portable guns. Constructed of 28 railway sleepers and 12 ties, these structures were first called Pile portable platforms; but they quickly became known as Pile mattresses, named for Gen Frederick A. Pile, the antiaircraft artillery commander (fig. 9). In late June the British began to replace their static guns (fig. 10) with mobile guns; and they put better gun predictors into action in early July. The most difficult problems remaining involved damaged V-1s falling on London and interference between fighter pilots and gunners.[18]

Hill and Pile concluded that they should designate an all-



***(Photo Credit: Imperial War Museum)***

**Figure 9. Preparing Pile mattress.**



*(Photo Credit: Imperial War Museum)*

Figure 10. 3.7-inch gun mounted on a Pile mattress.

gun belt from which all aircraft should be excluded. As this idea emerged, a staff officer suggested moving the guns and radar to the coast. Such a relocation would eliminate the problem of damaged missiles falling on London and would provide radar operators and gunners optimum visibility. This scheme would also give the fighter pilots a clear boundary (the coastline) between the gun and aircraft zones (fig. 11). Almost simultaneously, Robert A. Watson-Watt, the eminent scientist and developer of radar, independently came up with the same concept, giving it even more weight.[19]

The plan had a number of dangers. First, there was the question of effectiveness. Would the new concept actually improve the defenses? The fighter pilots, who claimed 883 of the 1,192 V-1 kills as of 13 July, would be inhibited by a split zone. Second, how long would such a redeployment—entailing hundreds of heavy guns, thousands of personnel, and tens of thousands of tons of supplies and equipment—take? What would happen to the defenses in

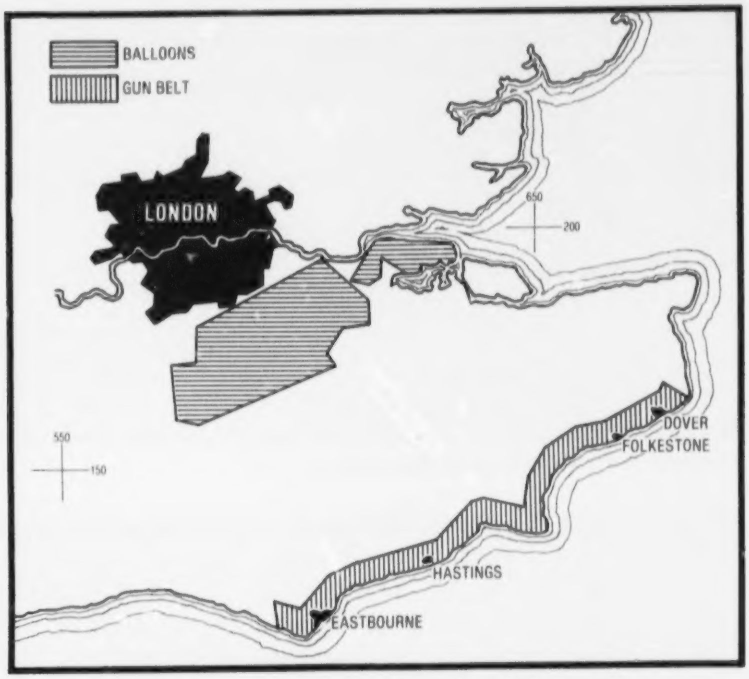


Figure 11. Final British defensive deployment.

the meantime? Finally, how long would it take to get a clear decision on this proposal? As each day passed, redeployment became increasingly difficult as more of the mobile guns were fitted with Pile mattresses and more guns were added to the gun belt.[20]

On 13 July Hill made the decision to create an all-gun belt on the coast. This bold, quick exercise of authority was remarkable, as was the speed with which the decision was implemented. By 17 July the heavy guns, radar, and supporting equipment and supplies were in place, followed in two days by the light guns. This action, which involved the movement of 23,000 people and about 60,000 tons of supplies, was no small feat. The British deployed the guns on the coast between Dover and Beachy Head, creating a zone extending 10,000 yards over the water and 5,000 yards in-land. Aircraft were restricted to altitudes above 8,000 feet in this area, but the fighter pilots were free to roam over the English Channel and over England between the gun belt and the balloon line.[21] Most important, the decision turned out to be an effective solution.

Although the redeployment and separation of the aircraft and guns was a major factor in the increased effectiveness of the defenses, there were other factors as well. The number of heavy guns in the coastal belt increased from 376 on 1 July, to 416 on 23 July, to 512 on 30 July, and to 592 on 7 August. In addition there were 892 40-mm guns and 504 20-mm guns plus 254 rocket tubes. The addition of new American radar (SCR-584) and predictors for the British 3.7-inch guns and the American 90-mm guns also helped the defenses.[22] Another technical improvement was the use of proximity fuzes that detonated at a preset distance from the target. The new fuze proved to be about five times more effective than either time or contact fuzes.[23] Finally, the gunners became more accurate as they got more practice.

These defensive improvements, coupled with the known direction, altitude, and speed of the V-1s, enabled the defenders to dramatically improve their effectiveness. Before the redeployment, the defenses downed 42.3 percent of the V-1s observed, after the redeployment, that figure rose to 58.6 percent. Another set of data, similar but not exactly coinciding, indicated that the defenses downed 48.4 percent of those missiles spotted over land before the redeployment and 84.1 percent of those spotted after the redeployment. The high point occurred on the night of 27/28 August when the defenders destroyed 90 of 97 missiles reported; only four V-1s got through to London.[24]

The increased power of the defenses resulted largely from the tremendous improvement in the effectiveness of antiaircraft artillery. The gunners got 21.5 percent of the destroyed credits before the redeployment and 53.9 percent afterwards. They downed 17 percent of their targets in the first week after redeployment and 74 percent in the last four days of action (29 August through 1 September).[25]

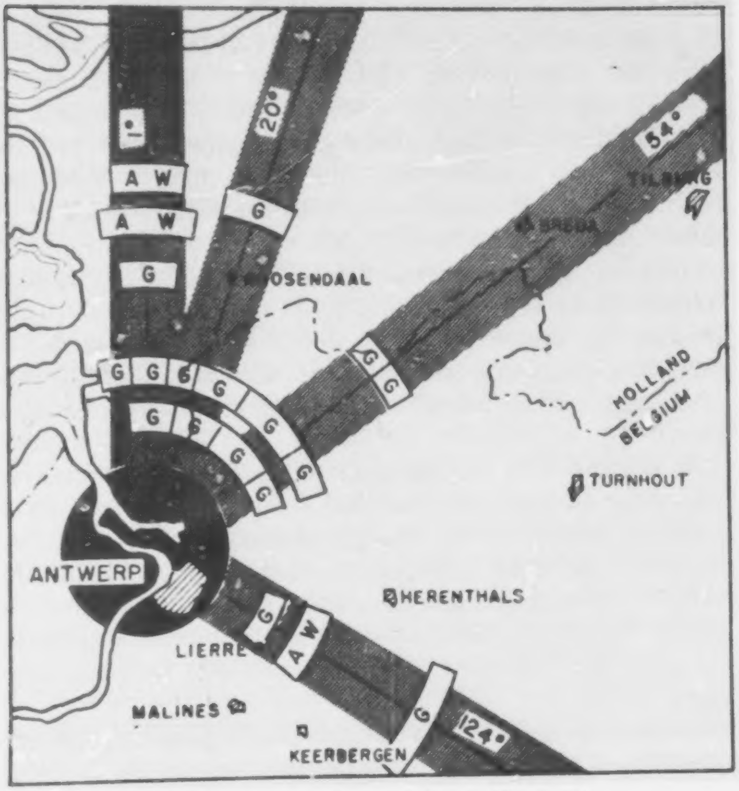
During the summer campaign, the Germans began to launch V-1s from bombers. The first air launch known to the British occurred on 6 April 1944 at Peenemünde, with the first recognizable use of an air-launched weapon against England on 9 July 1944. The German air force air launched about 90 V-1s before the redeployment and 310 V-1s from then to 5 September. With the withdrawal of German forces from the French launching sites, these air-launched weapons became the chief air threat to Britain in the closing months of the war. Between 5 September and the last air launching on 14 January 1945, the Germans hurled about 1,200 of these V-1s against Britain, but only 66 reached London.[26] Not only did few of the weapons reach London, but the accuracy was very poor. The final act in the V-1 campaign against Britain came in March 1945 when the Germans introduced a long-range version of the V-1. Fitted with a lighter wing and warhead, this V-1 variant could fly 220 miles compared to the standard missile's range of about 150 to 160 miles. The Germans launched the first modified V-1 from Dutch ramps on 3 March. From 3 March to 29 March, the Germans fired a total of 275 V-1s against Britain, only 13 of which reached London. The Allies had been tipped off by photoreconnaissance and intelligence reports about this new weapon, and they ordered the northern defenses bolstered on 27 February with reinforcements consisting of seven squadrons of day fighters and three squadrons of night fighters. But the antiaircraft artillery gunners performed so well that the British relieved all but one of the day squadrons. The defenders downed 72.8 percent of the 125 missiles observed.[27]

The Germans fired a total of about 10,492 V-1s against Britain, of which about 2,000 crashed shortly after takeoff. The defenders observed 7,488 missiles and downed 3,957 (52.8 percent); they credited fighter pilots with 1,847 kills, the gunners with 1,878, and the balloons with 232.[28] Efficiency improved from downing 42.3 percent of the V-1s observed before the redeployment (12 June to 15 July) to 58.6 percent after the redeployment (16 July to 5 September). The guns downed 63.2 percent of the air-launched missiles after this period (16 September 1944 to 14 January 1945) and 33.1 percent of the ground-launched V-1s from Holland. Put another way, the percentage of V-1s that reached London, relative to those launched, declined in these same periods (29.1, 23, 5.5, 4.7) for an overall figure of 23.1 percent. Thus, about 2,419 V-1s reached the London Civil Defence Region, killing 6,184 civilians and seriously injuring another 17,981 with about another 5 percent of the total casualties consisting of service personnel. Approximately 92 percent of the casualties were in the London area.[29]

To put the V-1s into perspective, they must be compared with other German weapons that killed and maimed British civilians during World War II. German bombings killed 51,509, V-2s killed 2,754, and long-range guns 148. Of the 146,777 British civilian casualties (killed and injured) in World War II: 112,932 were caused by bombings, 24,165 by the V-1s, 9,277 by the V-2s, and 403 by long-range guns.[30]

Another aspect of the V-1 operational story is frequently overlooked. The Germans also launched about 7,400 to 9,000 V-1s against targets on the continent, mostly (4,900) against the port of Antwerp, Belgium. In the city's defense the Allies deployed 18,000 troops manning 208 90-mm guns, 128 3.7-inch guns, and 188 40-mm guns. In addition, they used 280 balloons later augmented to 1,400. No fighters were employed in the defense of Antwerp (fig. 12).[31]

In the attack on Antwerp, the Germans deployed their first missiles from the southeast. In mid-December, they shifted to the northeast and finally, by the end of January, to the north. The last direction of attack created a particular problem for the defense because a large airfield in that sector was not closed until 21 February 1945. Nevertheless, the defenders downed 2,183 (91.2 percent) of the 2,394


20°
54°
A W
A W
G
OSENDAAL
BREDA
TIL G
HOLLAND
BELGIUM
TURNHOUT
ANTWERP
HERENTHALS
LIERRE
MALINES
KEERBERGEN
124°

*(Photo Credit: US Army Air Defense Artillery Museum)*

**Figure 12. Defense of Antwerp. Although the Germans had lost control of the skies, they were able to bombard area targets such as the port of Antwerp with V-1s.**

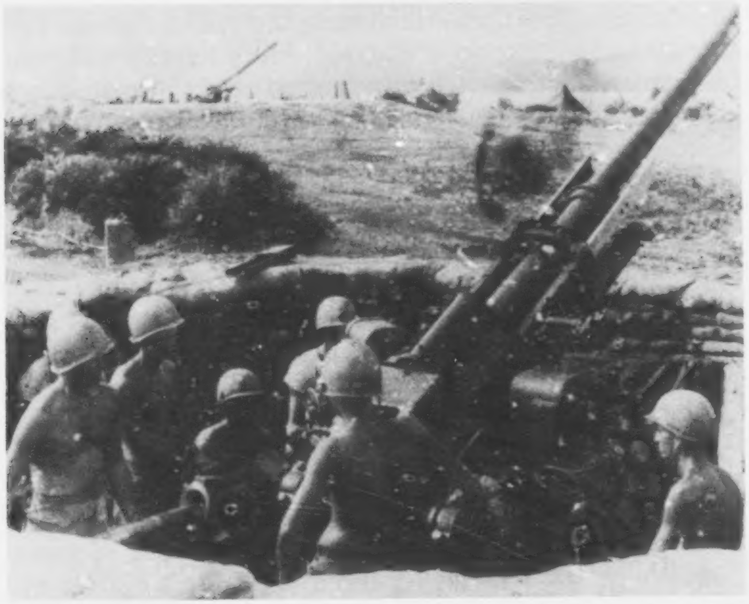
missiles plotted. More to the point, only 211 V-1s reached a 7,000-yard radius area around the docks that the defenders designated as the vital area.[32]

The Germans also attacked Liège, Belgium, with about 3,000 V-1s. It was defended between 23 November and 11 December 1944, when the urgent needs of the Battle of the Bulge pulled the defenders out.

V-1s killed a total of 947 military and 3,736 civilians and wounded 1,909 military and 8,166 civilians on the continent. Antwerp suffered 1,812 military and 8,333 civilian casualties, or 10,145 of the 14,758 V-1 casualties on the continent.[33]

## American Antiaircraft Artillery

American flak also made an impressive showing in combat (fig. 13). During the Normandy campaign (7 through 30 June 1944), First Army antiaircraft gunners claimed 96 aircraft destroyed of 682 enemy sorties. Following the breakout from the invasion beachhead, between 31 July and 6 August, the Luftwaffe hurled 1,312 aircraft at American



*(Photo Credit: US Army Air Defense Artillery Museum)*

Figure 13. US 90-mm M-1 AAA gun.

forces passing through difficult terrain at the Avranches bottleneck. Although the US gunners downed only 58 aircraft, the Germans did not hit a single bridge, dam, or vital target.[34]

On 3 December 1944 the Luftwaffe launched 80 to 100 aircraft against the First Army and lost 30 to 41 aircraft in a 45-minute engagement. During the Battle of the Bulge (16 December 1944 through 1 January 1945), the First Army antiaircraft units claimed 366 German aircraft destroyed or probably destroyed of 1,178 sorties.[35]

The most spectacular one-day Allied air defense effort took place on New Year's Day 1945. The GAF plan called for about 900 German fighters, led by Ju-88 night fighters, to attack 16 Anglo-American airfields. Coordination broke down badly as German flak downed about 100 of their own aircraft before they reached Allied lines. Poor weather, lack of training, confusion, Allied flak, and Allied fighters further diluted the impact of the raid. Allied losses were much lower than might have been expected, and German losses were much higher. The German air force claimed to have destroyed 402 Allied aircraft on the ground and 65 in the air; but the Allies put their own losses at 236 destroyed and badly damaged on the ground and 23 in air-to-air combat. The Germans put their own losses at 304 aircraft destroyed and 232 pilots lost. Anglo-American pilots claimed 102 aerial victories, and Allied gunners claimed 185 to 394 (the former figure, confirmed kills; the latter, confirmed kills plus those awaiting confirmation). The Allies recovered 137 German aircraft wrecks in their area of control and, from their remains, credited the fighters with 57 kills and flak with 80.[36]

A clearer view of the confused battle is perhaps possible by focusing on the attack of one airfield. The German fighter unit JG11 launched about 65 fighters against the Anglo-American airfield (Y-29) at Asch, Belgium, where four RAF Spitfire squadrons (41st, 130th, 350th, and 610th) and two US fighter groups (352d and 366th) were stationed. When the Germans struck Asch, one Spitfire squadron and one Thunderbolt squadron were airborne, and a dozen P-51s of the 352d Fighter Group were taking off. The latter's group commander, Col John Meyer, claimed one FW 190 before he had raised his landing gear. In the ensuing melee, American pilots claimed 32 kills; British pilots, one. In all, the Allied pilots and gunners at Asch claimed 35 to 41 German aircraft out of 50 attackers. The Allies lost no P-51s and only one P-47 in the air; they lost seven Spitfires and several C-47s on the ground. The Germans admitted losing 27 aircraft in the attack.[37]

A few months later, US flak gunners scored another impressive victory. After American forces unexpectedly captured the railway bridge across the Rhine River at Remagen, Germany, on 7 March 1945, German forces made considerable and desperate efforts to destroy it. By 14 March the American antiaircraft gunners massed 64 90-mm, 216 40-mm, 24 37-mm guns, and 228 quad and 140 single .50-caliber machine guns in their defensive effort. They claimed 142 German aircraft destroyed of 442 attacking. More important, German aircraft did not damage the bridge.[38]

During the European campaign, American forces of the 12th Army Group (First, Third, and Ninth US Armies) recorded 14,776 sorties by the German air force. US gunners claimed the destruction of 2,070 Luftwaffe aircraft. The German air force recorded 29,953 aircraft lost to enemy action or missing in the entire war. Of the 14,938 downed over Germany, the Germans credited antiaircraft artillery with the destruction of 2,598 aircraft.[39]

## German Flak Defenses

Of all combatants in World War II, the Germans had the most experience with antiaircraft defense. They had come a long way from the Versailles peace treaty that essentially banned German antiaircraft weapons. Although the Germans evaded the provision of the treaty to a degree, it clearly inhibited them from building any military force until Hitler came to power in 1933. In April 1934 the Germans assigned the antiaircraft arm to the Luftwaffe. At first, they considered antiaircraft artillery as the primary defense of the homeland from enemy aircraft. The Germans expanded the role of flak as they assessed the lessons of the Spanish Civil War, where antiaircraft artillery also served as an infantry support weapon. On the basis of that war, the Germans doubled the number of their flak units. So when World War II began, the Germans had 2,600 heavy and 6,700 light flak guns.[40]

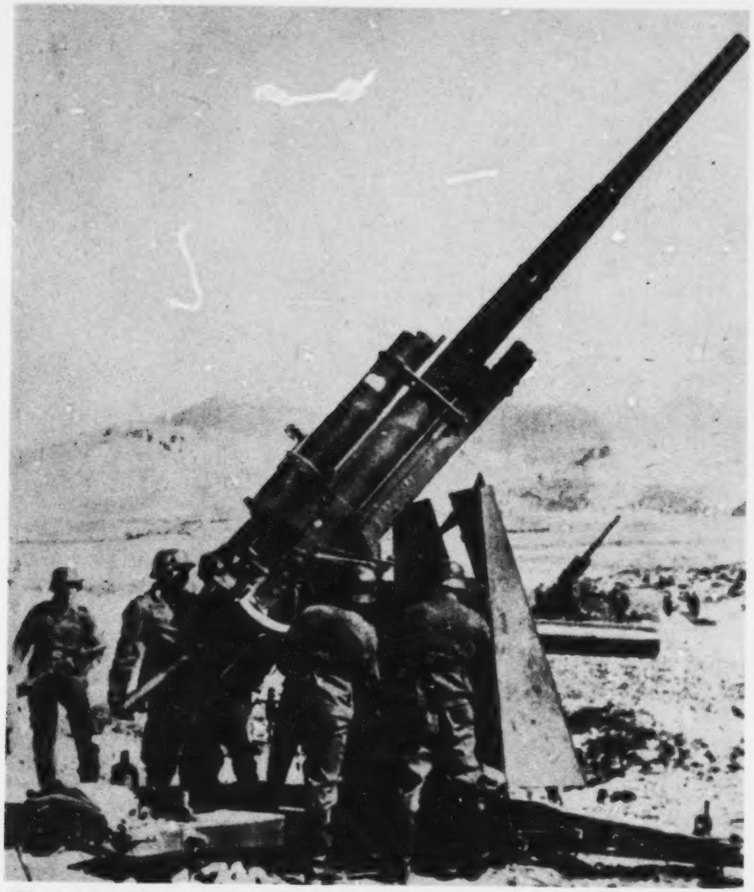
Germany's best-known artillery piece was the 88-mm gun (fig. 14). Although a gun of that caliber was used in World War I, Krupp designers at Bofors in Sweden worked out the details of a new 88-mm gun in the interwar years and returned to Germany with the new model in 1931. The resulting 8.8-centimeter (cm) Flak 18/36/37 comprised about 60 percent of Germany's heavy flak guns during World War II. The gun fired a 20.3-pound shell at a muzzle velocity of 2,690 fps to an effective ceiling of 26,000 feet.*

The fame of the 8.8 stems mainly from its versatility as a triple-purpose weapon (antiaircraft, antitank, and standard artillery piece) and its ubiquity (fig. 15). The Germans began to work on a more advanced model—the 8.8-cm Flak 41—in 1939, but did not get this gun into service until 1943. In spite of early mechanical problems, this flak gun had greater performance** as well as a lower silhouette on its turntable mounting than did the 8.8-cm Flak 18/36/37 on its pedestal mounting (fig. 16). Because of its high cost

---

*Compare these figures with the standard British heavy antiaircraft gun, the 3.7-inch Mark 3, and the American 90-mm Mark 1. The former fired a 28-pound projectile at a muzzle velocity of 2,600 fps to an effective ceiling of 32,000 feet, whereas the latter hurled a 23-pound shell at 2,700 fps to an effective ceiling of 32,000 feet. The two Allied guns weighed more than the German gun and had a higher rate of fire, 20 rpm compared with the German 15-rpm gun.[41]

**It fired a 20.7-pound shell at a muzzle velocity of 3,280 fps to an effective ceiling of 37,000 feet.

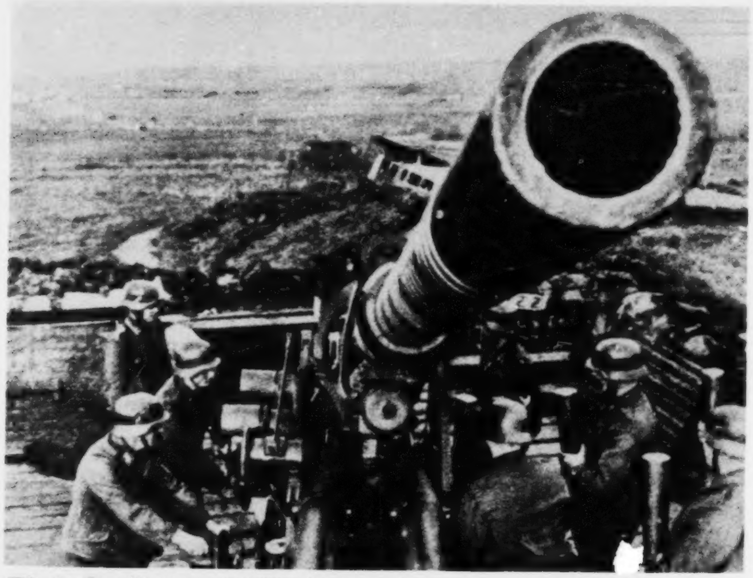


***(Photo Credit: Imperial War Museum)***

**Figure 14. The German 88-mm gun was probably the most famous and feared artillery piece of World War II.**

and complexity, the Germans manufactured relatively few of this model and, in February 1944, fielded only 279.[42]

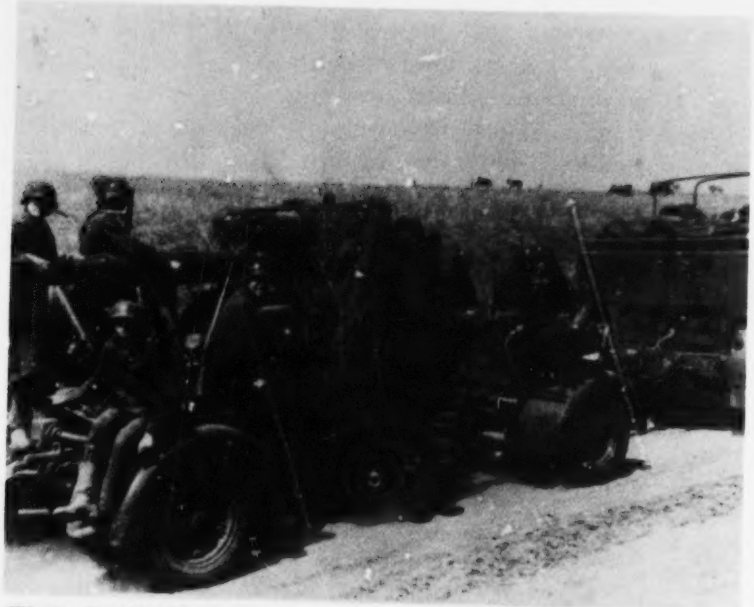
In 1933 the Germans established the specifications for a 105-mm antiaircraft gun, and three years later selected Rheinmetall's proposal over Krupp's. The 10.5-cm Flak



*(Photo Credit: Imperial War Museum)*

**Figure 15. One reason for the 88's fame was its versatility; it served well in conventional artillery, antitank, and antiaircraft roles.**

38/39 fired a 33.2-pound shell at a muzzle velocity of 2,885 fps to an effective ceiling of 31,000 feet. In 1936 Rheinmetall also won a contract for a 12.8-cm gun designated as the 12.8-cm Flak 40. It fired a 57.2-pound shell at 2,890 fps to a maximum ceiling of 35,000 feet. Compared with the 88-mm gun, the 128-mm gun (fig. 17) used a powder charge four times as great and thus its shell's flight time was only one-third as long. In late 1944 there were 116 105-mm flak guns mounted on railroad mounts, 827 on fixed mounts, and 1,025 on mobile mounts. For increased mobility the Germans mounted about 5 percent of their 105-mm and 128-mm flak guns on railroad cars. These potent guns were manned by Germany's best flak gunners and were correctly considered to be the cream of the flak arm.[43]

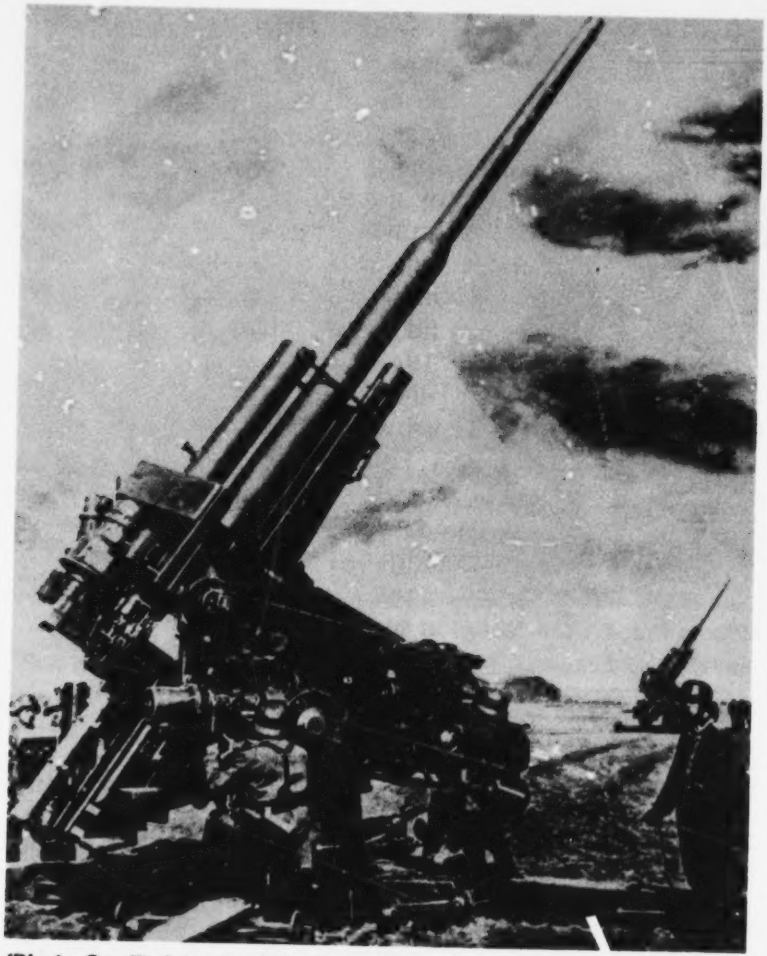


**(Photo Credit: USAF Historical Research Center)**

**Figure 16. 88-mm gun on the march.**

In the early years of the war (1939–41), flak protected German troops from the few Allied aircraft that the German air force had not destroyed and supported the advancing armies as an antitank and direct support weapon. In the Western European campaign of 1940, flak units claimed 854 of 2,379 aircraft destroyed and over 300 armored vehicles. By October 1941 German flak gunners claimed a score of 5,381 aircraft and 1,930 armored vehicles.

Another victory, partially due to German flak, was the evacuation of Axis forces over the Strait of Messina from Sicily in August 1943. Despite Allied air and sea superiority, almost 40,000 German and 62,000 Italian troops left the island with much of their equipment, nearly 10,000 vehi-



(Photo Credit: Imperial War Museum)

Figure 17. German 128-mm gun.

cles, and even with their rear guard. This Axis victory resulted because of Allied preoccupation with the upcoming Italian invasion and completion of the conquest of Sicily, as well as the Axis employment of 500 heavy and light flak pieces.[44] But the Messina evacuation was as much an Axis accomplishment as it was an Allied failure.

During the early years, German home defenses faced light opposition as the British night raiders were few in number, ill equipped, and poorly trained (a bomber could rarely find its target, much less destroy it). But British airmen began to strike telling blows, as dramatically seen in the first raid of 1,000 bombers on Cologne in May 1942. Shortly afterwards, American heavy bombers joined the fray with daylight attacks, but they did not launch large raids on Germany until the spring 1943.

One key target was the oil complex at Ploesti, Romania. After an ineffective attack by 13 American B-24s on 12 June 1942, the Army Air Forces (AAF) dispatched 178 bombers on a low-level attack on 1 August 1943 (fig. 18). American airmen estimated Axis flak defenses at about 100 heavy guns and several hundred light guns but encountered twice that number. These guns, combined with the vulnerability of the Liberators at low altitude, confusion of the battle, and the long range (over 2,300 mile round-trip) of the mission, caused heavy bomber losses. A total of 54 bombers failed to return; the airmen attributed the bulk of these losses to flak (fig. 19).

The Allies conducted 19 high-level raids on Ploesti between 5 April and 19 August 1944 (fig. 20). On 5,479 effective sorties, American bombers dropped 13,469 tons of bombs and lost 223 bombers. Flak downed 131 bombers and 56 fighters.[45]

Besides the 21 heavy bomber raids by the AAF, there were four other bombing attacks on Ploesti. The RAF flew three night missions, dropped 313 tons of bombs on 186 effective sorties and lost 15 bombers to unknown causes. In contrast, on 10 June 1944, the Americans dispatched 46 P-38s, each carrying a 1,000-pound bomb and a 300-gallon fuel tank, escorted by 48 Lightnings, against the oil target. The airmen credited 38 P-38s with effective bombing sorties and with getting 19 bombs on target with good results.

Figure 18. The 1 August 1943 Ploesti mission was both dramatic and costly.

But the Americans met stiff resistance, including 100 enemy aircraft; as a result, they lost nine dive-bombers (seven to flak) and 14 of the escorting P-38s. American fighters claimed 28 enemy aircraft destroyed in the air.[46]

In early April 1944 German heavy guns at Ploesti numbered 178, light guns 203. The Germans bolstered this number to 278 heavy guns and 280 light guns by the time of the final attack on 19 August (figs. 21–25). The heavy guns (fig. 26) consisted of 128-mm guns (10 percent), 105-mm mobile guns (15 percent), 88-mm mobile guns (60 percent), and Romanian 75-mm guns and captured Soviet 76.5-mm guns (15 percent). Flak took an increasing toll of American bombers, rising from 1.2 percent of sorties in April to 2.4

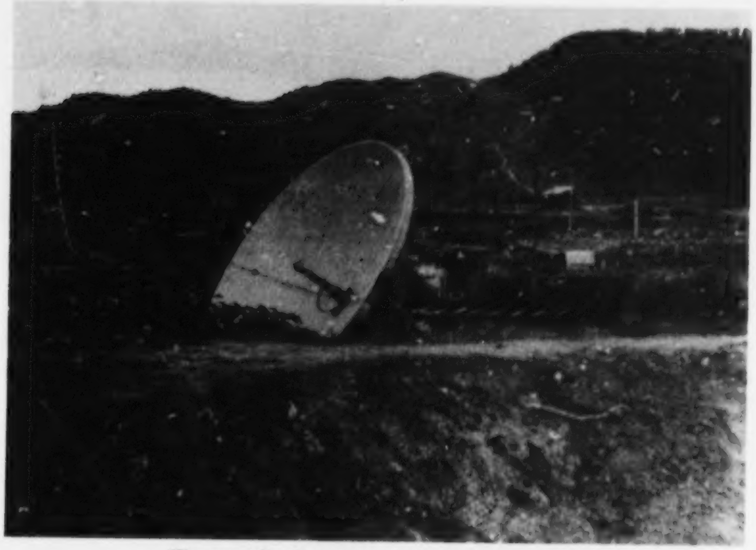


Figure 19. German radar in Romania.

percent in August, as losses to enemy aircraft declined from 2 percent of sorties to zero.[47]

The Germans fiercely defended other oil facilities as well. At Politz, they deployed 600 heavy antiartillery weapons and at Leuna, 700. At the latter, about 40 percent of the heavy weapons were larger than 88-mm guns. The campaign against Leuna, Germany's second largest synthetic oil and chemical plant, lasted from 12 May 1944 to 4 April 1945. The AAF sent 5,236 bomber sorties and the RAF sent 1,394 sorties, which dropped 18,092 tons of bombs on the target. But because of weather and enemy opposition, only 10 percent of those bombs fell on the plant complex. Bombing accuracy as measured in bombs on target declined from 35 percent in May 1944, to 5 percent in July, and finally to 1.5 percent in September. On three missions in October, the Germans reported that no bombs fell on the plant. The Americans lost 119 bombers (2.3 percent of

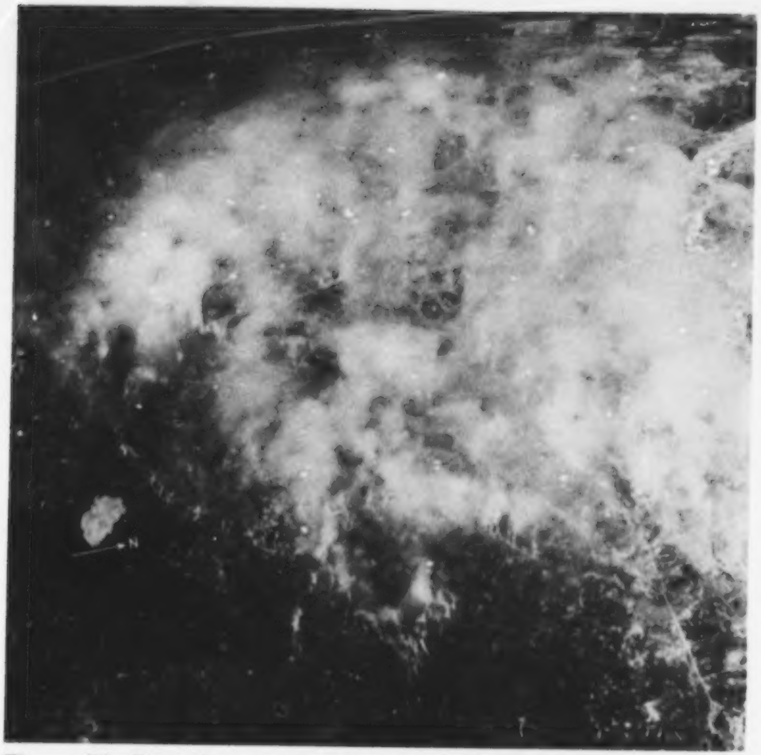
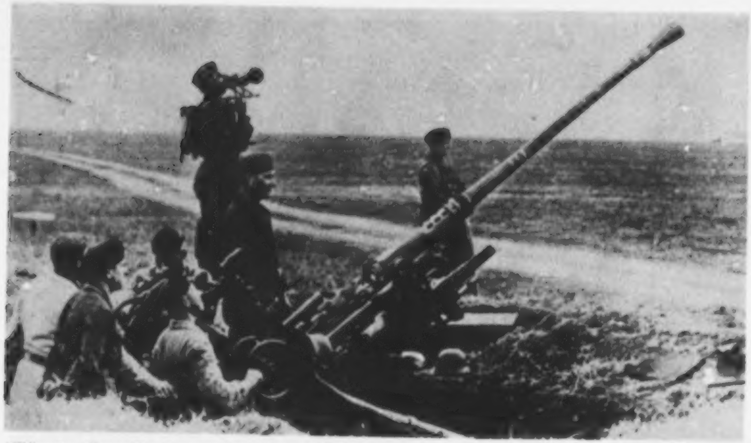


**Figure 20.** **Ploesti was protected by smoke as well as by guns. Smoke screen is shown developing on 17 August 1944. Romana Americana Oil Refinery is at center right. White dots are bomb craters.**

sorties), while the British lost eight (.57 percent), mostly to German flak.[48]

The Germans stoutly defended other targets as well. Hamburg's defenses included 400 heavy guns, while Munich's had almost 300, and Vienna's had 327. The Allies hit the Austrian capital on 47 raids and lost 361 heavy bombers, 229 (63.4 percent) to flak. On 7 February 1945 the Fifteenth Air Force lost 25 of the 689 aircraft sent against Vienna (19 to flak). The Fifteenth Air Force hit the city again the next day, but this time it lost none of its 470



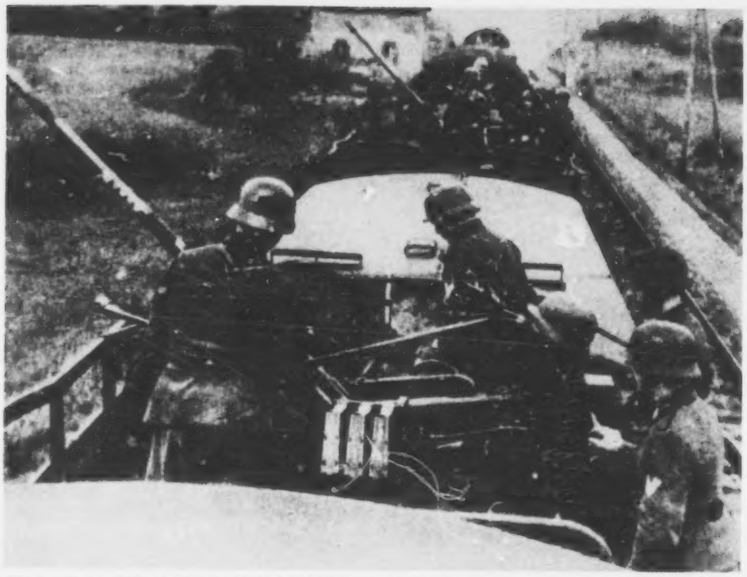
*(Photo Credit: Imperial War Museum)*

**Figure 21. German light flak was also very effective. German single 20-mm mount. Note German soldier in background operating a range finder.**

bombers. The losses on the first raid were due to the clear weather that helped the gunners and to the Americans' lack of airborne coordination and electronic countermeasures (ECM). The success on the following day was attributed to poorer weather (7/10 to 10/10 overcast) and better American coordination and ECM.[49]

The Germans introduced technological improvements to increase flak efficiency. In 1941 flak units began to get gun-laying radar and grooved projectiles. These shells fragmented into 80- to 100-gram pieces instead of the usual 1- to 7-gram pieces, therefore causing much greater damage. Incendiary shells also increased flak efficiency by three times, according to German estimates.

Another important advancement dealt with fuzes. Having requested double fuzes (contact and timed) in 1943, the Germans introduced them in late 1944. These fuzes increased the effectiveness of 88-mm guns five times, 105-mm guns three times, and 128-mm guns two times. But the



*(Photo Credit: Imperial War Museum)*

**Figure 22. German 20-mm guns aboard train.**

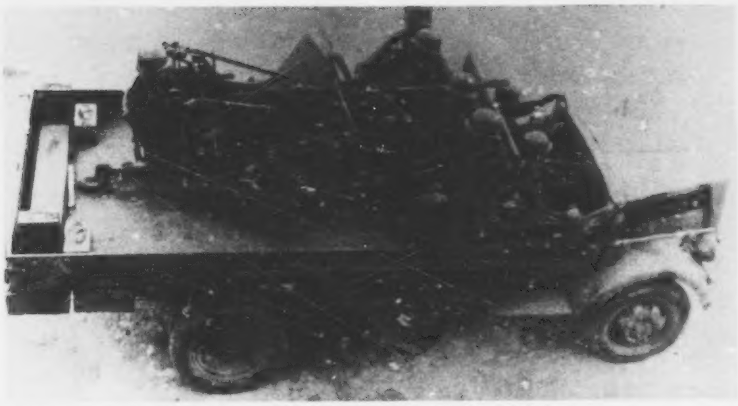
Germans did not make the big change in fuzes; instead, the Allies introduced proximity fuzes. After the war, an American study calculated that had the Germans used proximity fuzes, they could have increased their flak efficiency by a factor of 3.4, making B-17 operations very hazardous and B-24 operations impractical.[50]

The Germans also experimented with a number of novel approaches to ground-based antiaircraft systems. They tested squeeze bore and sabot devices* but got neither into service.

The Germans examined yet another concept, flak rockets,

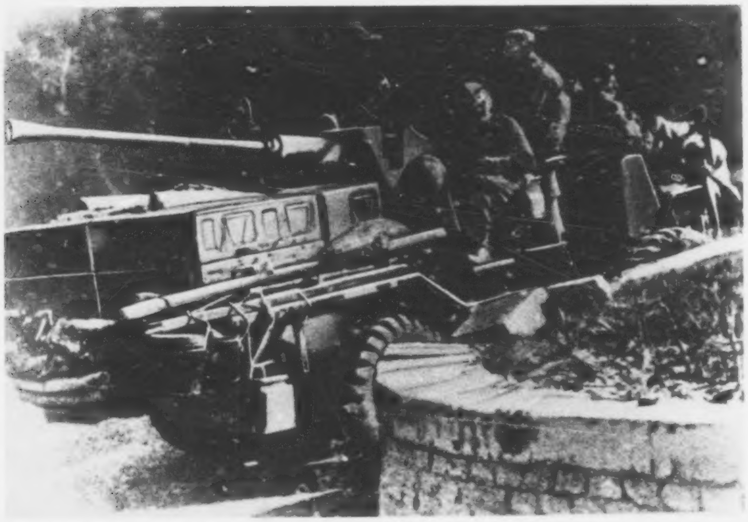
---

*In both systems a gun fires a shell of smaller size, for example, a 88-mm shell from a 105-mm gun. Because more powder pushes a smaller projectile, much greater velocity is achieved.



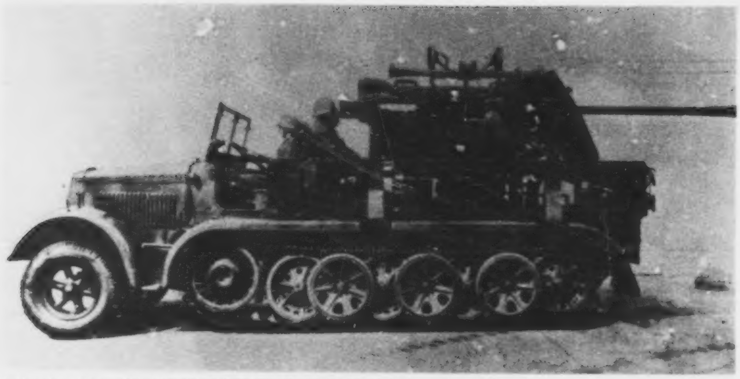
*(Photo Credit: USAF Historical Research Center)*

**Figure 23. German light flak pieces were also mounted on motor vehicles. Here a 20-mm gun is seen with a makeshift mount on an Opel truck.**



*(Photo Credit: USAF Historical Research Center)*

**Figure 24. 40-mm Bofors on truck chassis.**



*(Photo Credit: USAF Historical Research Center)*

**Figure 25. 50-mm gun on five-ton towing vehicle.**

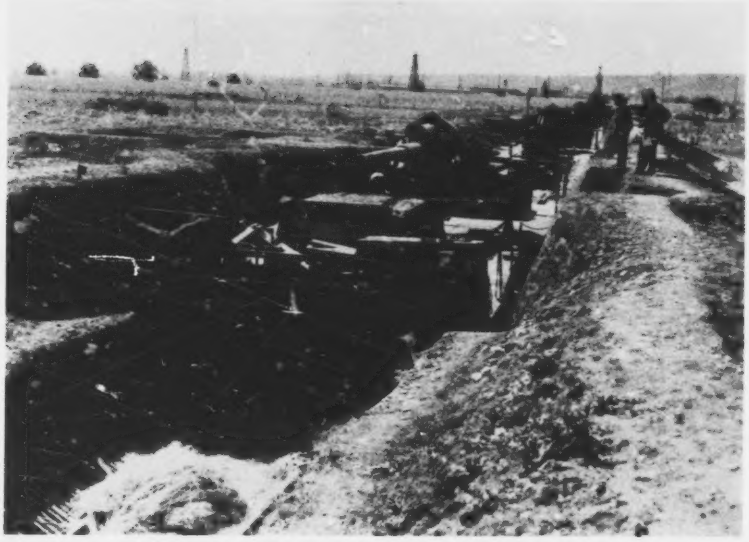


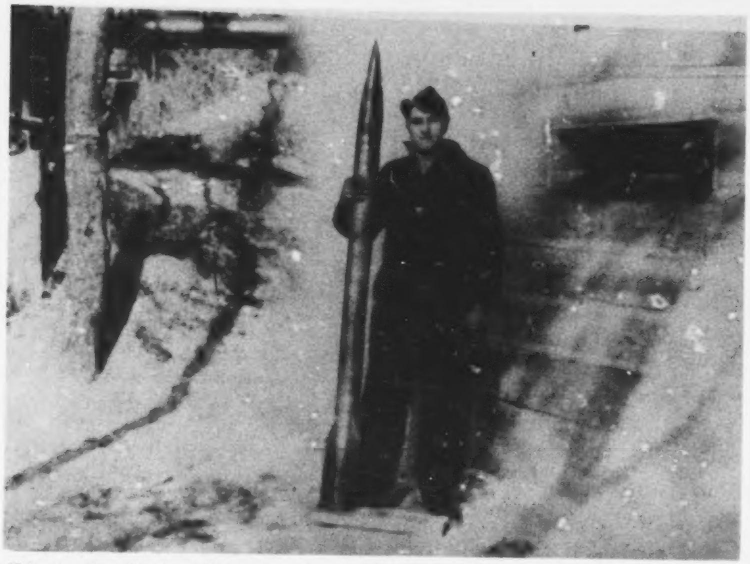
**Figure 26. 128-mm railway guns were largest in Ploesti, Romania. There were 24 of these, each of which could fire one shell every five seconds.**

but barely employed them in World War II. Since the Germans realized little positive results with the program in the 1930s, Hitler halted all long-range development projects in September 1941. The Germans lifted the stop order on the program, and in April 1942 they drew up the specifications for a variety of flak rockets, both guided and unguided. In September 1942 Hermann Goering authorized work on AAA rockets. In response, Wernher von Braun forwarded a study in November 1942 that mentioned three types of guided flak rockets: a 28-foot, single-stage solid-fuel missile; a 33-foot, two-stage solid-fuel missile; and a 20-foot, single-stage liquid-fuel missile.[51]

Subsequently, the Germans developed a number of guided flak missiles and two small unguided ground-launched rockets, the Foehn and Taifun. The Foehn weighed 3.3 pounds and measured two feet in length. First fired in 1943, the rocket had a 3,600-foot range and was intended to be fired in ripples from a 35-barrel launcher. The Germans put three batteries into service and credited them with downing three Allied aircraft. The rocket's primary impact was, however, psychological.[52]

The other unguided flak rocket, the Taifun (fig. 27), measured 75.6 inches in length, weighed 65 pounds, and carried a 1.4-pound warhead. The Germans fired the liquid-fuel rockets in ripples from either a 30-barrel launcher or a 50-barrel launcher mounted on a 88-mm gun carriage. The Taifun had an altitude capability of 46,000 to 52,000 feet.[53]

In addition, the Germans developed four guided rockets: Enzian, Rheintochter, Schmetterling, and Wasserfall. The Enzian (fig. 28) also could have passed for an aircraft, albeit a radio controlled and tailless one. (It was an unmanned version of the rocket-powered Me 163.) Almost 12 feet in length, the missile's sweptback wing spanned 13.5 feet. It weighed 4,350 pounds and was launched by four solid-fuel boosters from a 88-mm gun carriage. The Enzian carried a 660-pound warhead to an altitude of 53,000 feet and a slant range of 16 miles at 560 mph. The Germans tested

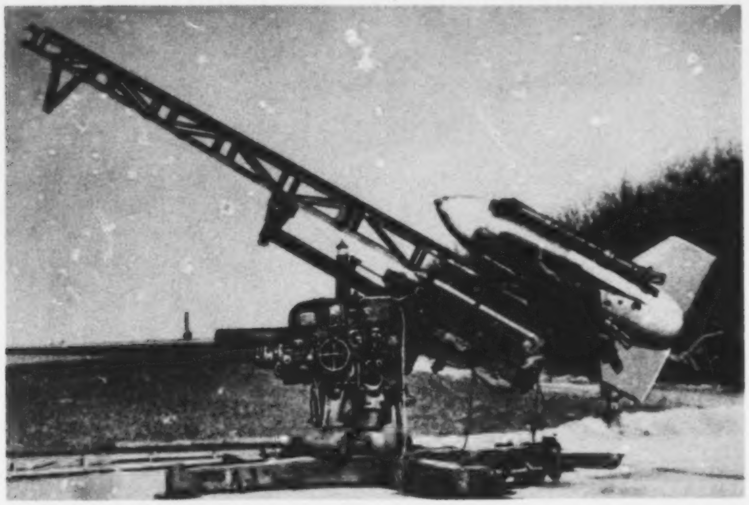


*(Photo Credit: Smithsonian Institution Photo No. 41183)*

**Figure 27. German Taifun rocket, an unguided, liquid-propelled antiaircraft rocket.**

possibly 38 Enzians. But only a few were successes; and in January 1945 the Germans canceled the project.[54]

Rheintochter I (fig. 29), a solid-fuel, two-stage rocket, measured 20.1 feet and weighed 3,860 pounds. The second stage had four canard fins and six wings (which spanned 9.8 feet) and carried a 220- to 330-pound warhead to a slant range of 18,000 yards and an altitude of 23,000 feet. The Germans first tested the radio-controlled device in August 1943; and by the time it was canceled in February 1945, they had fired 88 flak rockets. Rheintochter I's unsatisfactory performance led to Rheintochter II, which had four jettisonable booster rockets between its wings. Rheintochter III used the same first stage, but its second stage was about 3.5 feet longer. Powered by a liquid-fuel engine, it used two booster units. The Germans tested about 40 of



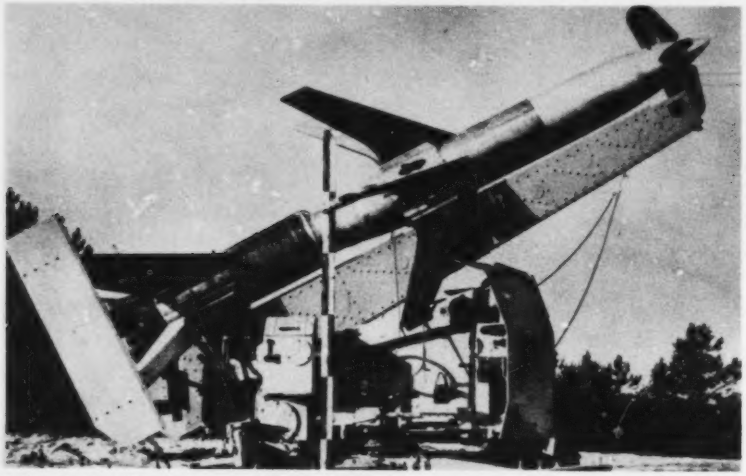
*(Photo Credit: Imperial War Museum)*

**Figure 28. The Germans tested the Enzian but dropped it in favor of other German flak rockets. Note the solid-fuel boosters mounted on the missile's fuselage.**

these before canceling Rheintochter in favor of the Schmetterling.[55]

The Schmetterling (fig. 30) looked like a sweptwing aircraft measuring 11.8 feet in length and 6.6 feet in span. At an all-up weight of 970 pounds, it was launched by two solid-fuel boosters from a 37-mm gun carriage. The radio-controlled missile carried a 51-pound warhead out to a maximum slant range of 17,500 yards and an altitude of 29,000 feet at a maximum speed of 537 mph. The Germans first fired it in January 1944 and tested perhaps 80 despite engine (fuel regulation) problems.[56]

Wasserfall (fig. 31), the largest German flak rocket, was a scaled-down V-2, from which it was derived.[57] Unlike the V-2, however, Wasserfall had a set of four fins mounted about one-third down its 25.6-foot length, and larger tail fins. Wasserfall had a lift-off weight of 8,400 pounds and

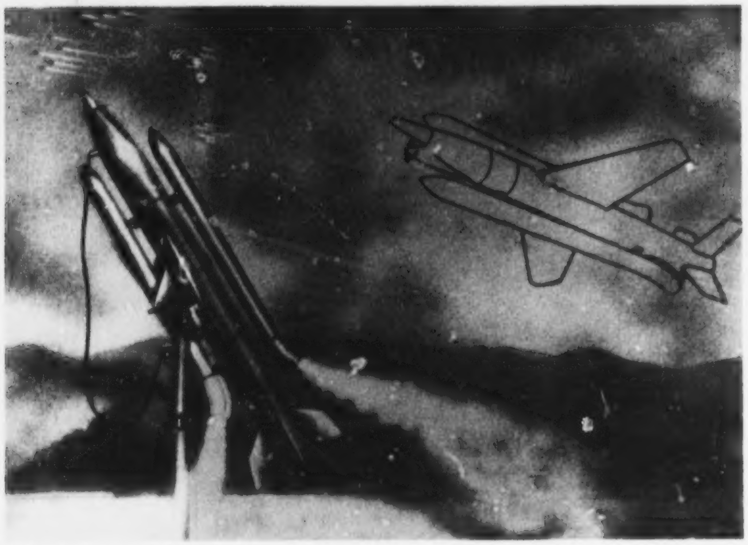


***(Photo Credit: Imperial War Museum)***

**Figure 29. Another German flak rocket experiment was this Rheintochter.**

carried a 200-pound warhead. The Germans desired a missile that could down an aircraft flying 540 mph at an altitude of 12 miles and at a distance of 30 miles. The Wasserfall fell short of these requirements by only reaching an altitude of 6 miles at a distance of 30 miles, an altitude of 9 miles at 25 miles, and an altitude of 11.4 miles at 16.5 miles. But American bomber formations in 1945 were flying less than 200 mph at about an altitude of 5 miles. The Germans intended to use beam-rider guidance, in which the missile rides along an electronic beam to its target. But telemetry difficulties created problems. The Germans had two schemes for detonating the warhead: ground-activated signals and a proximity fuze. Design work for the Wasserfall was completed in early 1943, and the missile was first flown in February 1944. The Germans tested at least 50 before canceling the project in February 1945.[58]

Some authors speculate on what might have been if the

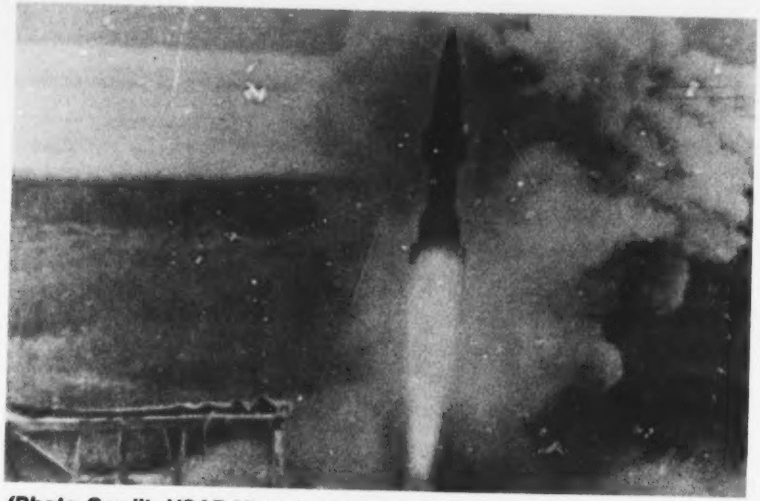


*(Photo Credit: USAF Historical Research Center)*

**Figure 30. German Schmetterling.**

Wasserfall, the most promising flak rocket, rather than the V-2, had been built in quantity. They overlook some basic factors. The antiaircraft problem is much more difficult than that of ground bombardment; the target is small, possibly maneuvering, and fast moving. The Germans lacked an operational proximity fuze; and the Allies had a lead in electronics that probably could have nullified, certainly degraded, the German's radio-controlled guidance system.

A number of problems inhibited German flak. Flak personnel declined in quality, especially after 1943 as Germany combed out its forces to make good the war's heavy attrition. The Germans employed women, old men, young boys, factory workers, foreigners, and even prisoners of war in flak units. In November 1944, 29 percent of flak personnel were civilians and auxiliaries; in April 1945, 44 percent. Understandably these individuals were less than satisfac-



**(Photo Credit: USAF Historical Research Center)**

**Figure 31. Wasserfall test at Peenemünde, fall 1944.**

tory. The increasing number of guns deployed by the Germans consumed tremendous amounts of materials, causing another difficulty—the shortage of ammunition, which, in early 1944, forced the Germans to restrict their firing. By the end of the war, flak units could deliver only half of their firepower potential because of these shortages.[59]

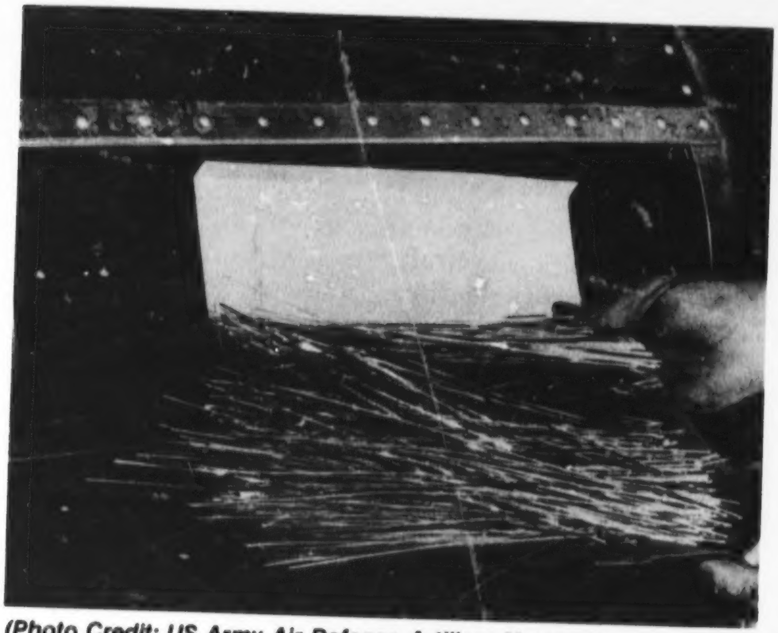
Nevertheless, German flak was effective in World War II and grew increasingly effective as the war continued. Through 1944 German gunners inflicted about one-third of Allied aircraft losses and two-thirds of the damage; and after that, about two-thirds of the losses and almost all the damage. To be precise, not only did German flak become more effective through the course of the war but, as German aircraft became less effective, the flak gunners picked up the increasing burden. The AAF lost 18,418 aircraft in combat against Germany in World War II. The American airmen credited antiaircraft artillery with downing 7,821 of these, enemy aircraft with 6,800.[60]

In addition to downing and damaging Allied aircraft, flak also degraded bombing accuracy. A 1941 British report said the accuracy had been degraded by a figure of one-third. A similar study of Eighth Air Force bombing errors between May 1944 and February 1945 credits almost 40 percent of these errors to enemy guns. The Mediterranean Air Forces put the same message across in another way—with little or no flak opposition, the fighters required 30 bombs to hit a bridge; but against intense flak it took 150 bombs per hit. Medium bombers not encountering flak destroyed 21 percent of the bridges attacked and completely missed only 3 percent, but against flak the bombers destroyed only 2 percent and completely missed 28 percent.[61]

## Allied Countermeasures

Allied airmen used a number of measures to reduce the effectiveness of enemy flak. Planners picked routes around known flak positions, used higher bombing altitudes, employed saturation tactics, and devised tighter formations. Two other measures deserve detailed treatment.

The importance of radar as both an early warning and gun-laying device grew as Allied bombers increasingly operated at night and in poor weather. Fortunately for the Allies, the British held a marked advantage over the Germans in electronic warfare; some say a two-year lead. One countermeasure used against German radar was called either window (by the British) or chaff (by the Americans) (fig. 32). Aircraft dropped strips of foil, similar to Christmas tree tinsel, which caused false signals on German radarscopes. The RAF first used this electronic countermeasure in the July 1943 Hamburg raids, following a command decision that cleared its use after being withheld for almost 18 months. The second major ECM device, called carpet, electronically jammed German radar. In October 1943 the Allies first employed the device in bomber formations as



*(Photo Credit: US Army Air Defense Artillery Museum)*

**Figure 32. Chaff.**

both a broad band and spot jammer. Estimates vary on the impact of ECM; and ECM impact changed as specific conditions changed, especially weather. Although the ECM device may have decreased the effectiveness of flak by as much as two-thirds, an overall estimate of one-fourth is probably closer to the truth.[62]

The AAF used more direct tactics as well. On the first day of the Market-Garden operation, 17 September 1944, the AAF attacked 112 flak positions. In addition to over 3,000 tons of bombs dropped by B-17s, P-47s dropped 36 tons of fragmentation bombs and expended almost 123,000 rounds of 50-caliber machine-gun ammunition. The relatively light losses suffered by the attackers, the troop carriers, and gliders indicate that the effort worked.[63] This was not the case the next day. On 18 September 1944, 38 P-47s of the crack 56th Fighter Group attacked German flak positions in the Turnhout area with .50s and parachute fragmentation bombs. Disaster ensued. Low overcast, haze, and orders requiring pilots to hold their fire until fired upon inhibited the American pilots and put them at a disadvantage. The unit lost 15 aircraft to German flak and one aircraft to Allied antiaircraft fire; in addition, of the 22 aircraft that returned home, 13 were damaged by flak.* That day, the AAF flew 104 sorties against antiaircraft guns and lost 21 aircraft with another 17 damaged. These missions claimed 18 flak guns destroyed.[64]

In the entire Market-Garden operation, Allied airmen claimed destruction of 118 flak positions and damage to 127 others. But the Anglo-Americans lost 104 aircraft on 4,320 sorties (excluding troop carriers and gliders), of which 37 were lost on 646 sorties to suppress flak. Analysis of the entire operation indicated that flak suppression succeeded only on the first day of the operation.[65]

Not surprisingly then, the next month, US Strategic Air Forces in Europe recommended against attacking heavy flak positions with low-flying aircraft. The writer based his report on the opinions of the three American numbered air forces in Europe (the Eighth, Ninth, and Fifteenth Air Forces), which agreed that such attacks would be ineffective and costly. The report concluded that alternative measures (ECM, formations, evasive maneuvers, and fragmentation bombing) were more practical.[66] American airmen found little profit in attacking flak positions in World War II. As Maj Gen Elwood "Pete" Quesada, commander of the 9th Tactical Air Command, put it: "It was like a man biting a dog."[67]

The Americans also employed artillery to fight flak. Artillery was used to blanket known flak positions as the fighters approached. The American gunners attempted to pin down the flak gunners so that the fighters could launch their initial attack against minimal resistance. These tactics were employed with mixed results during the June 1944 siege of Cherbourg, France.[68]

---

*Eleven pilots, three injured, got back to Allied lines while three others were killed and two captured. Of 338 Eighth Air Force fighters lost to flak during the war, 77 percent were lost while strafing.

Another Allied effort at flak suppression occurred during the Anglo-American airborne assault across the Rhine River at Wesel on 24 March 1945 in Operation Varsity. Allied aircraft and artillery attempted to silence or neutralize the 922 German flak barrels in the area. Allied bombers flying 3,741 sorties dropped over 8,100 tons of bombs on flak positions during the three days before the airdrop. The Ninth Air Force medium bombers dropped 517 tons of bombs on 265 sorties, while RAF bombers dropped 88 tons of bombs on 71 sorties. RAF Typhoons used bullets, bombs, and rockets. In addition, Allied artillery fired 24,000 rounds (440 tons) at 95 German positions. Despite this awesome firepower, the Allies accomplished little. Allied airmen and artillery men scored few hits and, at best, temporarily lowered the morale of the German gunners. Nevertheless, German flak inflicted considerable casualties on Allied forces (figs. 33–35). In addition to destroying 53 tow and 16 supply aircraft, the Germans damaged 381 of 853 American gliders and 160 of 272 British gliders, of which 142 had major damage.[69]

## Fratricide

One problem that antiaircraft gunners would rather not talk about is firing on and hitting friendly aircraft. Fratricide in the speed and confusion of battle is as understandable as it is regrettable. Ground troops and antiaircraft gunners had fired on friendly aircraft in World War I and formed the attitude: "There ain't no such thing as a 'friendly airplane'."[70] That attitude and that problem continued.

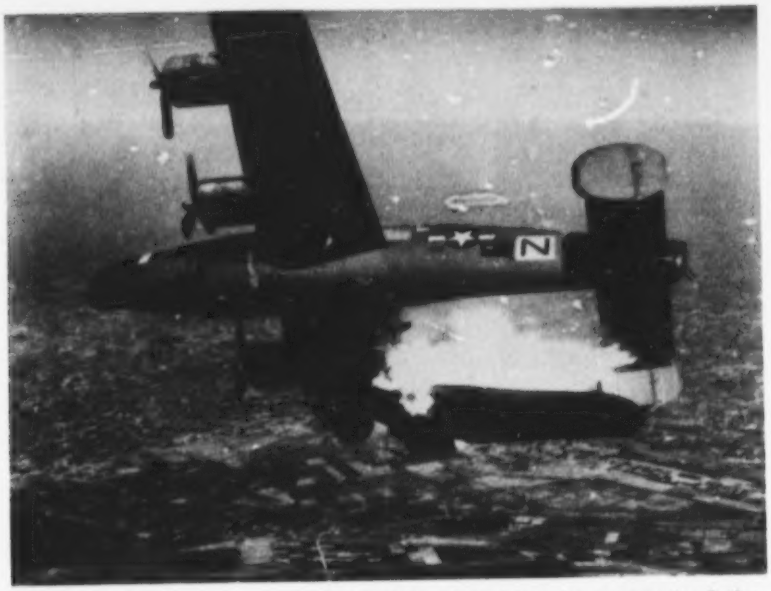


**Figure 33. Liberator over Italy. After bombing in support of the Eighth Army drive in northern Italy, this B-24 Liberator of the US Army Fifteenth Air Force has been hit by flak. Two men bailed out of the burning plane.**

The most costly Allied fratricide incident in World War II occurred on the night of 11/12 July 1943, when the Allies attempted to reinforce the Sicily invasion with elements of the 82d Airborne Division. Gen Matthew B. Ridgway, the division's commander, anticipating difficulties, attempted to get a protected aerial corridor for his forces and got assurances from both the US Navy and the US Army antiaircraft gunners. Unfortunately, Ridgway's worst fears were realized. The troop-filled C-47s and the gliders arrived over the invasion fleet shortly after an Axis bombing raid. The first flight passed without incident, but then one gun opened fire and acted as a signal for Allied gunners both ashore and afloat to cut loose at the rest of the aerial armada. Antiaircraft fire destroyed 23 of the 144 aircraft that departed Africa that night and badly damaged 37 others.

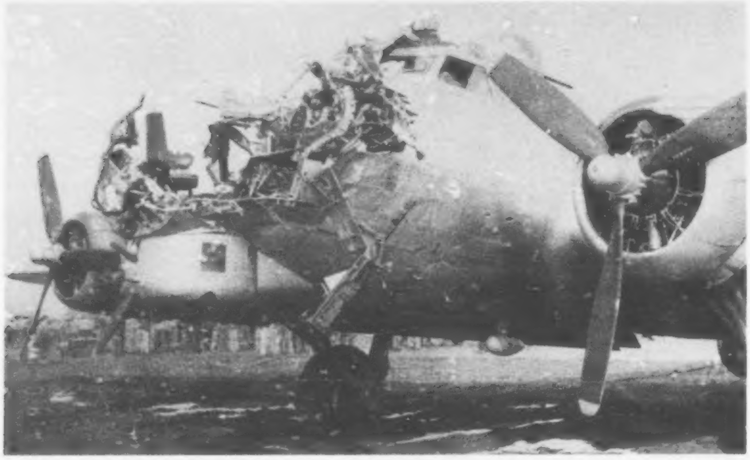


Figure 34. Some survived . . . somehow. The pilot landed this B-17 safely after its nose was literally shot away by flak over Cologne, Germany.

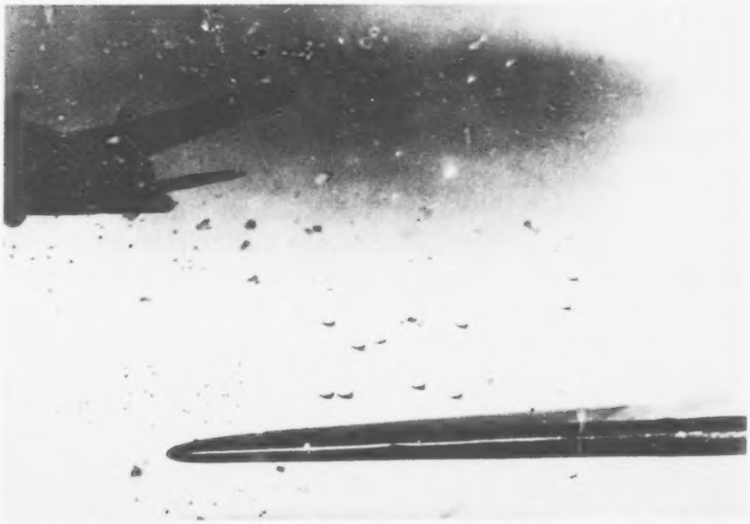


Figure 35. German flak was impressive. B-17 Flying Fortresses over Bremen, Germany.

Losses in personnel amounted to 97 paratroopers killed or missing and 132 wounded and 60 airmen killed or missing and 30 wounded.[71]

Two nights later, a similar incident occurred with slightly less disastrous results. American and British troop carriers attempted to drop British paratroopers to seize a bridge and establish a bridgehead on the east coast of Sicily. Friendly naval and ground fire engaged the transports, destroyed 11, damaged 50, and forced 27 others to abort the mission. Of the 87 aircraft that pressed on, only 39 got their troops within a mile of the designated drop zone. Thus, only 300 of the 1,900-man force reached their objectives; nevertheless, they carried it.[72]

Fratricidal problems continued throughout the war. Fortunately for the Allies, they proved less costly than the Sicily debacles. On D-day, for example, despite special invasion markings (white stripes), "friendly fire" hit a number of Allied aircraft. At 2025, guns aboard a landing craft downed two P-51s flying at 500 to 1,000 feet. Ten minutes later, Allied flak destroyed two more allied aircraft. At 2050, gunners fired on four Spitfires but apparently did not score any decisive hits. At 2130, however, Allied flak holed one Spitfire that was last seen smoking and losing altitude. At 2200, gunners engaged two Typhoons and appeared to hit both. These are the recorded cases; we can assume other incidents escaped without reporting.

The Allies instituted measures to prevent fratricide—employing electronic identification devices (identification, friend or foe—IFF), recognition signals, and restricted areas; but the problem continued. Between 22 June and 25 July, Allied gunners engaged 25 friendly aircraft and destroyed eight. Five of these aircraft, two Spitfires on 22 June and three P-51s on 26 June were destroyed after they attacked friendly forces. (In fact, there were at least 13 incidents of Allied aircraft attacking Allied forces between 20 June and 17 July 1944, killing at least two soldiers and wounding three others.) Fragmentary records indicate that

Anglo-American flak crews downed six Allied aircraft in August, two in October, and at least three in November. Even the brass could not avoid the problem. On 1 January 1945 US AAA units fired on an aircraft carrying AAF Generals Spaatz and Doolittle. Spaatz informed General Patton of his gunners' poor aircraft recognition and shooting skills. The 8th Fighter Command lost seven fighters to Allied flak. US gunners admitted engaging 15 friendly aircraft and destroying 12, all of which the gunners asserted were either committing a hostile act or flying in a restricted zone. US gunners complained that lack of identification restricted them from engaging one-third of 6,000 targets.*[73]

Following the 26 June incident with the three US P-51s, the 9th Tactical Air Command restricted free-lance strafing within 10 miles of the bomb line; only prearranged missions were to be flown in that area. The armies established restricted areas that by 7 September 1944 constituted an almost continuous belt from Antwerp, Belgium, to Nancy, France. British Bomber Command protested that this restriction inhibited their operations, and so the Allies limited the zones without satisfying either party.[74]

The problem of fratricide was, of course, not limited to the Allies or to the European theater. All warring powers had the problem—for example, the German fighter attack on Allied airfields on 1 January 1945. In the Pacific between December 1943 and June 1944, the US Navy downed at least six of its own aircraft and two or three AAF B-25s.[75] The worst case was probably at the Cape Gloucester, Bismarck Archipelago assault that began on 26 December 1943. American naval antiaircraft fire downed two B-25s and one P-47 and damaged two other B-25s. US ground gunners also destroyed an American night fighter. Apparently, naval gunners fired on "anything that was not a P-

---

*Just as the subject of fratricide is neglected, so is the issue of enemy aircraft not engaged. Only one example should be required to make the point: American radar detected aircraft flying toward Pearl Harbor prior to the attack but could not identify them.

38," the readily identifiable twin-boom American fighter. The Marines credit friendly antiaircraft fire with downing three of their aircraft during the war.[76]

## The US Navy in the Pacific

The US Navy made strenuous efforts to defend its ships against enemy aircraft. During World War II, it spent over $4 billion on this problem, almost half of this amount on ammunition. As a result, the Navy estimated that although the US naval effort really did not begin until the spring of 1940, its antiaircraft guns increased their effectiveness 100 times from the start to the finish of the war. Mid- and short-range, light antiaircraft guns presented the major problem because existing armament (.50-caliber machine guns and 1.1-inch guns) proved inadequate. The US Navy turned to foreign guns, the 20-mm Swiss Oerlikon and the 40-mm Swedish Bofors.

The Navy estimated that the 20-mm cannon was eight to 10 times as effective as a .50-caliber machine gun and in 1935 bought some of the Swiss Oerlikons, even though Army and Navy aircraft used the French Hispano Suiza 20-mm guns. By war's end, the Navy had 12,561 of the 20 mms shipboard and had spent $787 million for one billion rounds of 20-mm ammunition. The investment paid off. Between Pearl Harbor and September 1944, the 20-mm guns downed 32 percent of all Japanese aircraft claimed by Navy guns and 25 percent after that date. Although the 20-mm gun did have certain advantages over heavier guns, the 40 mm began to replace it toward the end of the war.[77]

The Bofors 40-mm gun was the most widely used antiaircraft piece of World War II. By 1939 the Swedes delivered the Bofors to 18 countries and concluded production licenses with 10 other countries. Thus, both sides used, manufactured, and captured Bofors during the war.

The Navy's interest in the Bofors 40-mm gun began in the fall of 1939; and in late August 1940, guns and equipment arrived in the United States. Tested in September, the Bofors guns proved superior to both the US 37 mm and the British two pound (pom pom). The US government signed a contract in June 1941 and installed the first 40-mm Bofors gun aboard ship early the next year. But there were problems in manufacturing the Bofors. First, the original metric drawings had to be converted to English measurements; then it was found that two manufacturers used different systems—York decimals and Chrysler fractions. As a result, parts for the American-made guns were not completely interchangeable. At first 200 parts differed, but this number was eventually reduced to 10. By June 1945 the US Navy had 5,140 40-mm guns in dual and quad mounts. These guns claimed about 18 percent of the Japanese aircraft destroyed through June 1944 and about 50 percent between October 1944 and March 1945.[78]

The United States experimented with dual-purpose (antiship and antiaircraft) guns in the 1920s, produced the 5-inch/38-caliber gun in the early 1930s, and installed it on a destroyer in 1934. The gun had a horizontal range of 10 miles, a vertical range of 6 miles, and could fire 12 to 15 rounds per minute. The Navy increased the number of these guns from 611 in July 1940 to 2,868 in June 1945.

A major advance in the increased effectiveness of the heavy caliber gun came with the introduction of proximity fuzes. The Navy first fired the proximity fuze in January 1942, and in its first simulated combat test that August downed three drones with four shells. In the proximity fuze's first combat engagement on 5 January 1943, the USS *Helena* downed a Japanese bomber with its second salvo. The Navy estimated that the proximity fuzes increased antiaircraft artillery effectiveness three to four times. The fuze helped account for the high percentage of Japanese aircraft claimed by the 5-inch/38-caliber guns, 31 percent through the first half of 1944.[79]

## Japanese Antiaircraft Artillery

Japanese antiaircraft artillery lagged behind that of the other major powers from the beginning to the end of the war. The Japanese lacked the technological and manufacturing base to deal with their air defense problems and to make good their deficiencies. In addition the Japanese received only limited assistance from the Germans and also failed to fully mobilize their civilian scientists.[80]

The most widely used Japanese heavy flak piece was the 75-mm type 88 that entered service in 1928. It fired a 14.5-pound shell at a muzzle velocity of 2,360 fps to 23,550 feet but was inaccurate above 16,000 feet. The Japanese stuck with this gun throughout the war, while the Americans, British, and Germans went to larger and better performing weapons. Not that the Japanese did not try to upgrade their weapons—they produced an improved 75-mm gun (75-mm type 4) in 1944 but built only 65 and got few into action. Likewise, the Japanese put a 120-mm gun into production in 1943 but built only 154. Only two 150-mm guns saw service. The Japanese also used a few 88-mm naval guns. Associated equipment, especially radar and fire control equipment, also proved inadequate in numbers and outdated in performance.[81]

In 1941 the Japanese deployed 300 antiaircraft guns in defense of the home islands. By March 1945 they deployed 1,250, and by the end of the war over 2,000. The bulk of their heavy guns (509 to 551) guarded Tokyo—in August 1945, 150 naval 88-mm, 72 120-mm, and two 150-mm guns. Thus compared with the Germans, the Japanese deployed fewer and less-capable guns.

Little wonder that Japanese flak proved less effective than that of the other combatants. On the basis of overall losses and losses per sortie, the air war against Germany was much more costly to the AAF (18,418 aircraft and 1.26 percent of sorties) than the air war against Japan (4,530 aircraft and .77 percent of sorties).[82] In the entire war, the AAF credited Japanese flak with destroying 1,524 AAF aircraft, Japanese fighters with 1,037 (fig. 36).*

In the strategic bombing campaign against Japan, the AAF used their best bomber, the Boeing B-29, which was faster, higher flying, and heavier armed than either the B-17 or B-24 used against Germany.[83] The AAF lost 414 B-29s in combat against Japan. They calculated that 74 fell to enemy aircraft, 54 to flak, and 19 to both flak and fighters. The ineffectiveness of Japanese flak is highlighted by the American decision to change from their prewar bombing doctrine and European strategic bombing practice of high-altitude day attacks to night attacks below 10,000 feet. This decision resulted from poor bombing results, not because of aircraft losses, although 35 bombers had been lost on 814 sorties (4.3 percent) on daylight high-altitude attacks. Consequently, the B-29s attacked Tokyo at low altitudes at night and suffered slightly fewer casualties (39 aircraft on 1,199 sorties, 3.2 percent); at the same time bombing effectiveness greatly increased. The American airmen went on to burn out Japanese cities and towns with conventional weapons. The reduced and bearable attrition resulted from Japanese flak deficiencies and employment of such American measures as saturating the searchlight defenses, ECM, desynchronizing the propellers of the bombers to inhibit Japanese sound-controlled searchlights, and use of high-gloss black paint. The rate of B-29 losses to flak and flak plus fighters decreased steadily after peaking in January 1945 at 1.06 percent of sorties (fig. 37). In numbers of aircraft lost, April 1945 was the worst month with 22 B-29s lost. Tokyo was the most bombed (4,300 of 26,000 sorties) and the best defended of the Japanese targets. Tokyo's defenses accounted for 25 of the 55 flak losses of the Twentieth Air Force and for 14 of its 28 losses to flak plus fighters. American losses were much lighter at the other

---

*Japanese antiaircraft artillery did better proportionally against the US Navy than against the US Marine Corps, claiming 1,545 of 2,166 Navy aircraft lost in combat as compared with 437 of 723 Marine aircraft.

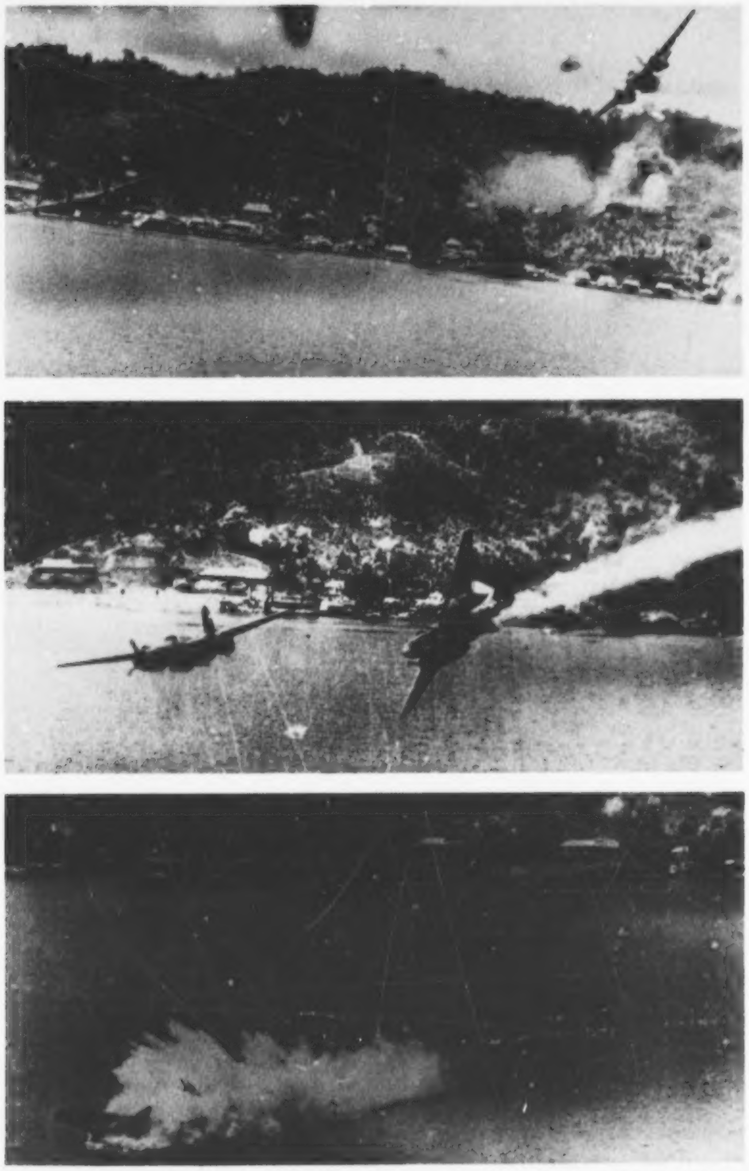


**Figure 36. Douglas A-20s attack Japanese positions at Karos, Dutch New Guinea. Note sequence of attack.**

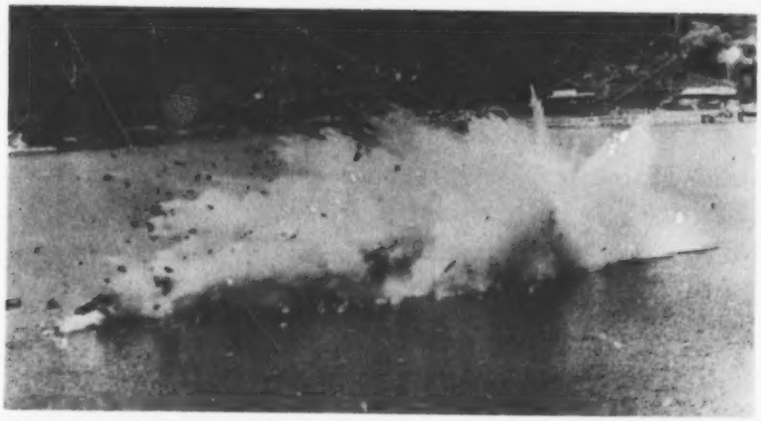


Figure 36. Douglas A-20s attack Japanese positions at Karos, Dutch New Guinea. Note sequence of attack (continued).

Figure 37. Although not as effective as German flak, Japanese flak did inflict losses on US aircraft. Boeing B-29 hit on bombing run over Japan, 26 June 1945.

targets that were not as well defended. For example, in flying 4,776 night sorties at low and medium altitudes against major Japanese cities, the Twentieth Air Force lost 83 bombers (1.8 percent) as compared with seven lost on 7,550 sorties (.1 percent) under similar conditions against secondary cities.[84]

## The Lessons of World War II

Like all major wars, World War II provided many lessons. As the first true air war, this conflict was especially valuable for the airmen. But the airmen of all countries tended to overlook or disregard flak. Although the war indicated the value and lethality of flak, the airmen looked instead to lessons that better fit their designs. The airmen's attitude changed little from the interwar years when they considered flak to be of little use and not worth the effort. The result of this disdain would be evident in the wars that would follow.

In retrospect, at least six flak lessons emerge from World War II. First, flak proved to be lethal and effective—downing more US aircraft than any other enemy weapon. Clearly, it was the big killer from early 1944 on. Concentrations of guns demonstrated the ability to seriously inhibit or nullify aerial operations such as the case of the V-1 campaign, the fall-winter 1944 oil campaign, and operations against the Remagen Bridge.

Second, flak made low-level operations very costly. Flak downed most of the American fighters lost during the war, the bulk of these in strafing attacks.[85] A number of missions emphasized the dangers of low-level operations; the most notable were the Ploesti mission of August 1943, flak suppression at Arnhem, the Netherlands, in September 1944, and the German attack on Allied airfields in January 1945.

A third lesson that can be gleaned from the war is that the airmen came up with countermeasures to antiaircraft artillery that would be standard for the future. The airmen attempted to avoid areas of flak concentrations by flying irregular courses in the face of ground fire, by flying only one pass over the target, and by using both the sun and terrain for maximum protection. They also employed chaff and jammers to degrade radar equipment, especially during the night or in poor weather. Finally, the airmen attacked the guns directly. But in most aircraft-versus-gun duels, the gunners had the advantage. Combat experience indicated that pitting a highly trained pilot and an expensive aircraft against a less-trained crew and less-valuable gun made little sense.

Fourth, rapidly evolving technology tilted the offensive-defensive balance in favor of the defense. Radar was the first and most important piece of equipment. It overturned the carefully constructed theories of Douhet and others (such as instructors and students at the Air Corps Tactical School), who believed that the bomber would always get through. Electronic countermeasures nullified somewhat the benefit of radar to the defense, but radar still gave the defenders early warning and more accurate aiming information than was previously available. The proximity fuze gave another big boost to the defenders, increasing the effectiveness of the guns by a multiple of five or more. One technological advancement that was in the development stages but did not see service during the war was flak rockets or, as they would later be known, surface-to-air missiles (SAMs). These devices were capable of reaching altitudes well above that of the highest-flying World War II bombers and fitted with proximity fuzes would have inflicted heavy casualties on the border formations.

Fifth, flak proved very cost-effective, downing hostile aircraft at a relatively low cost. But flak effectiveness cannot be measured by kills alone. Ground fire complicated the airman's task, forcing him to carry additional equipment and adopt additional procedures, all of which detracted from his primary job. Flak defenses also decreased bombing accuracy.

A final lesson of the war concerned the difficulty of correctly identifying aircraft. In short, the gunners were never able to adequately sort out the friendlies from the foes. Not only did friendly fire down friendly aircraft—most dramatically demonstrated by Allied troop carriers over Sicily in July 1943 and German fighters on 1 January 1945—but frequently friendly fire did not engage hostile aircraft. Despite electronic equipment, codes, procedures, briefings, and restricted zones, the problem persisted and accidents happened.

## NOTES

In this note system, information within the brackets indicates the location of the material and, in the case of Air Defense School Library, Air University Library, US Air Force Historical Research Center, Directorate of Combat Development, and Royal Artillery Institute, their call numbers. The following abbreviations are used: Air University Library, Maxwell AFB, Alabama [AUL]; Air Force Historical Research Center, Maxwell AFB, Alabama [AFHRC]; Naval Historical Center, Washington, D.C. [NHC]; Royal Artillery Institute, Woolwick, United Kingdom [W]; US Army Air Defense School, Fort Bliss, Texas [ADS]; US Army Command and General Staff College, Fort Leavenworth, Kansas [L]; US Army, Directorate of Combat Developments, Fort Bliss, Texas [DCD].

1. P. T. Cullen, "Air Defense of London, Paris, and Western Germany" (Paper, Air Corps Tactical School, n.d.), 7, 9, 28, 99, table 5 [AFHRC-167.404-11]; "Antiaircraft Defences of Great Britain: 1914 to 1946," appendix A [W-552]; US Army Air Defense School, "Air Defense: An Historical Analysis" (U), 1965, vol. 1:8 [AUL-M39991-

4] (SECRET—Information extracted is unclassified); "Antiaircraft Gun Trends and Scientific and Technical Projection: Eurasian Communist Countries," July 1981, 1-1.

2. US Army Air Defense School, "Air Defense," 21, 29, 30; Cullen, "Air Defense of London," 94; Extracts from Conference on Anti-Aircraft Defense, Military Intelligence Division, France, no. 8312, 26 December 1923 [AFHRC-145.91-534]; A. F. Englehart, "Antiaircraft Defenses: Their Development During the World War" (Paper, Air Corps Tactical School, circa 1934), 6, 9 [AFHRC-248.101-20]. American machine guns got another 41 German aircraft. Charles E. Kirkpatrick, *Archie in the A.E.F.: The Creation of the Antiaircraft Service of the United States Army, 1917–1918* (Fort Bliss, Tex.: Air Defense Artillery Museum, 1984), 85–86.

3. Maj Gen B. P. Hughes and Brigadier N. W. Routledge, Woolwick, United Kingdom, interview with author, October 1982; Air Corps Tactical School, "Antiaircraft Artillery," text, 1 November 1932 [AFHRC-168.69-9]; Louis P. Smithey and Charles K. Atkinson, "Development of Antiaircraft Artillery," *The Coast Artillery Journal*, January–February 1946, 70–71; William J. Wuest, "The Development of Heavy Antiaircraft Artillery," *Antiaircraft Journal*, May–June 1954, 23.

4. Theodore Ropp, *War in the Modern World* (Durham, N.C.: Duke University Press, 1959), 289.

5. "Antiaircraft Defences of Great Britain"; Frederick A. Pile, *Ack-Ack* (London: Harrap, 1949), 73. One American wrote in his 1929 Air Corps Tactical School thesis that flak was not worth the effort, which was the view of bomber proponents on both sides of the Atlantic. Kenneth Walker, "Is the Defense of New York City from Air Attack Possible?" research report, Air Corps Tactical School, May 1929, 30 [AFHRC-248.211-28A].

6. Pile, *Ack-Ack*, 100, 157, 181, 183; "Antiaircraft Defences of Great Britain"; Maj Gen B. P. Hughes interview; US Army Air Defense School, "Air Defense," 2:122–24; Frederick Pile, "The Anti-Aircraft Defence of the United Kingdom from 28th July, 1939 to 15th April, 1945," supplement to the *London Gazette*, 16 December 1947, 5978 [AUL-940.54 G7861 #38149]; "History of A. A. Command," n.d., 14 [W-C3/53].

7. Pile, *Ack-Ack*, 115; Pile, *London Gazette*, 5975; "History of A. A. Command," 14–15.

8. Pile, *Ack-Ack*, 186–93, 155–56, 379; Pile, "Anti-Aircraft Defence of the United Kingdom from 28th July, 1939 to 15th April, 1945," 5982; "History of A. A. Command," 123–24, plates XLV, LXIX; "Antiaircraft Defences of Great Britain," appendix B.

9. US Army Air Defense School, "Air Defense," 2:127–28, 131–32; H. E. C. Weldon, "The Artillery Defence of Malta," *Antiaircraft Journal*, May–June 1954, 24, 26, 27, 29; Charles Jellison, *Besieged: The World War II Ordeal of Malta, 1940-1942* (Hanover, N.H.: University Press of New England, 1984), 166–67, 170, 205, 258; Christopher Shores, *Duel for the Sky* (London: Blandford, 1985), 88, 90, 92.

10. Pile, *Ack-Ack*, 266, 301, 303, 305; Pile, *London Gazette*, 5984; "Survey of Antiaircraft Defenses of the United Kingdom," vol. 1, pt. 3:52, 53, 118 [W-MD1397].

11. Pile, *Ack-Ack*, 323–44; "Fringe Targets" [W-MD1397].

12. For a more detailed discussion of the V-1 and its operations in World War II, see Kenneth P. Werrell, *The Evolution of the Cruise Missile* (Maxwell AFB, Ala.: Air University Press, 1985), chap. 3. Basil Collier, *The Battle of the V-Weapons, 1944–1945* (London: Hudder and Stoughton, 1964), 56–59; Roderic Hill, "Air Operations by Air Defence of Great Britain and Fighter Command in Connection with the German Flying Bomb and Rocket Offensives, 1944–45," supplement to the *London Gazette*, 19 October 1948, 5587–89; Basil Collier, *The Defence of the United Kingdom* (London: Her Majesty's Stationery Office, 1957), 361, 365; British Air Ministry, "Air Defence of Great Britain, The Flying Bomb and Rocket Campaign: 1944 to 1945," first draft of report, vol. 7:42–43 [AFHRC-512.431A].

13. Collier, *V-Weapons*, 69, 71–75, 79; Hill, "Air Operations by Air Defense," 5591–92; Rowland F. Pocock, *German Guided Missiles of the Second World War* (New York: Arco Publishing, Inc., 1967), 48; Jozef Garlinski, *Hitler's Last Weapons* (London: Times Book, 1978), 168; David Irving, *The Mares Nest* (London: Kimber, 1969), 233, 236, 240; M. C. Helfers, *The Employment of V-Weapons by the Germans During World War II*, monograph (Washington, D.C.: Office of the Chief of Military History, Department of the Army, 1954), 18–30 [AFHRC-Film 31731, Frame 323].

14. Hill, *London Gazette*, 5594; Collier, *UK*, 374; Mary C. Welborn, "V-1 and V-2 Attacks Against the United Kingdom During World War II," technical report ORO-T-45 (Washington, D.C.: Johns Hopkins University Press, 16 May 1950), 9 [AFHRC-170.81-45]; "Minutes and Related Data Scientific Sub-Committee of Crossbow Committee, V-1, vol. 2," Operations Research Section (ADGB) Report 88, n.d. [AFHRC-142.0423-9]; Report of the British Air Ministry, "Points of Impact and Accuracy of Flying Bombs: 22 June–28 July," 29 July 1944 [AFHRC-512.6522-9]; "The Speed of Air-Launched Divers"; Report of the General Board, US Forces, European Theater, "Tactical Employment of Antiaircraft Artillery Units Including Defense Against Pilotless Aircraft (V-1)," study no. 38, 39 [AFHRC-502.101-38]; "Min-

utes and Related Data Scientific Sub-Committee of Crossbow Committee, V-1, vol. 2," S.B. 60093, 7 August 1944; Report of British Air Ministry, "Air Defence of Great Britain Tactical Memoranda I.G. no. 9675," 24 November 1944 [AFHRC-512.6522-9]; British Air Ministry, "Air Defence of Great Britain," 126; Hillery St. G. Saunders, *Royal Air Force, 1939, 1945*, vol. 3, *The Fight Is Won* (London: Her Majesty's Stationery Office, 1954), 165.

15. Hill, "Air Operations by Air Defense," 5592, 5594; British Air Ministry, "Air Defence of Great Britain," 121, 151, 179; Saunders, *Royal Air Force*, 165; Collier, *UK*, 380.

16. AC/AS, Intelligence, "Flying Bomb," 8; Mary C. Welborn, "Over-all Effectiveness of First US Army Antiaircraft Guns Against Tactical Aircraft" (Working paper, Johns Hopkins University, Washington, D.C., 18 January 1950), 6 [AUL-M35044-2#42]; Report of Supreme Headquarters Allied Expeditionary Forces (SHAEF), Air Defense Division, "Notes on German Flying Bomb," 22 August 1944 [AFHRC-506.6522C].

17. Pile, *Ack-Ack*, 330–33.

18. Hill, "Air Operations by Air Defense," 5592, 5594; SHAEF notes, 26 July 1944 [AFHRC-506.6522C]; Collier, *UK*, 375.

19. Hill, "Air Operations by Air Defense," 5596–97; British Air Ministry, "Air Defence of Great Britain," 133–35. For another suggestion for a coastal belt, see Lt Gen Carl Spaatz to supreme commander, SHAEF, letter, subject: The Use of Heavy Anti-Aircraft Against Diver, 11 July 1944 [AFHRC-519.161-7].

20. Collier, *UK*, 381–83; Collier, *V-Weapons*, 91–95.

21. Pile, *Ack-Ack*, 334–35; Hill, *London Gazette*, 5597; Collier, *UK*, 523.

22. British Air Ministry, "Air Defence of Great Britain," 130; AC/AS, Intelligence, "Flying Bomb," 8; SHAEF notes, 15 August 1944 [AFHRC-506.6522C].

23. British Air Ministry, "Air Defence of Great Britain," 106; Ralph B. Baldwin, *The Deadly Fuze* (San Rafael, Calif.: Presidio Press, 1980), 261–66.

24. Collier, *UK*, 523; Welborn, "V-1 and V-2 Attacks," table 2; Hill, *London Gazette*, 5599.

25. Collier, *UK*, 523; Welborn, "V-1 and V-2 Attacks," 10.

26. Hill, *London Gazette*, 5599, 5601; "Air Launched 'Divers' September and October 1944"; British Air Ministry, "Air Defence of Great Britain," 113; Collier, *UK*, 389, 391, 522; Saunders, *Royal Air Force*, 167–68; Seventeenth report by assistant chief air staff (Intelligence), "War Cabinet Chiefs of Staff Committee Crossbow," 22 July 1944 [AFHRC-142.0432-32]; Collier, *V-Weapons*, 119, 131.

27. Air Ministry Weekly Intelligence Summary 289 [AFHRC-142.423-15].

28. The antiaircraft artillery cost a third of what fighters cost and about 25 percent more than the balloons. Collier, *UK*, 523; Hill, *London Gazette*, 5603; British Air Ministry, "The Economic Balance of the Fly-Bomb Campaign," summary report, 4 November 1944 [AFHRC-512.675-3].

29. Memorandum 5-7B by US Strategic Air Forces, Armament and Ordnance, "An Analysis of the Accuracy of the German Flying Bomb (V-1) 12 June to 5 October 1944," 144 [AFHRC-519.6522-1]; British Air Ministry, "Air Defence of Great Britain," 123; Collier, *UK*, 523.

30. Collier, *UK*, appendix L.

31. European Theater report no. 38, 40–41, 45; Operations Report of Headquarters Antwerp X Forward, no. 2J, 1 May 1945, annex A [AFHRC-539.667-12]; SHAEF, "Report of 'V' Section on Continental Crossbow (September 1944–March 1945)," 28; United States Strategic Bombing Survey (USSBS), *V-Weapons (Crossbow) Campaign*, January 1947, 2d ed., 15.

32. Report of Headquarters Antwerp X Forward, no. 2H, 4 March 1945 [AFHRC-539.667-12]; Antwerp X report no. 2J, annex A; European Theater report no. 38, 40–45.

33. Peter G. Cooksley, *Flying Bomb* (New York: Scribner, 1979), 185. For a good secondary account, see R. J. Backus, "The Defense of Antwerp Against the V-1 Missile" (Masters of military arts and sciences thesis, US Army Command and General Staff College, 1971).

34. US Army Air Defense School, "Air Defense," 2:36; Welborn, "Over-all Effectiveness," table 8.

35. US Army Air Defense School, "Air Defense," 2:37; US Army, Antiaircraft Artillery note no. 8, 4 [L].

36. "The GAF 1 January Attack," United States Strategic Air Forces in Europe, Air Intelligence Summary 62 (week ending 14 January 1945), 5 [AFHRC-519.607A]; "Airfield Attack of 1 January"; SHAEF Intelligence Summary 42, 30 [L]; Daily Air Action Summary, Office of Assistant Chief of Staff, Intelligence Headquarters, Army Air Forces, Washington, D.C., 3 January 1945 [AFHRC-142.0323]; Duty Group Captain's Daily Résumé of Air Operations, serial no. 1843, Air Ministry, Whitehall, 2 January 1944 [AFHRC-512.6061A]; Saunders, *Royal Air Force*, 209; Roger A. Freeman, *The Mighty Eighth War Diary* (New York: Jane's Publishing Co. Ltd., 1981), 412–13; History and Statistical Summary, IX Air Defense Command, January 1944–June 1945, 80; Werner Gerbig, *Six Months to Oblivion* (London: Allan, 1973), 74, 76–79, 110, 112; *USAF Credits for the Destruction of Enemy Aircraft, World War II*, USAF Historical Study 85 (Maxwell AFB, Ala.:

USAF Historical Division, Air University, 1978), 286; Air Staff Operational Summary Report nos. 1503, 1504, Air Ministry War Room, 2, 3 January 1945 [AFHRC-512.306A]. The most detailed, but not necessarily most accurate, account is Norman Franks, *The Battle of the Airfields* (London: Kimber, 1982).

37. Gerbig, *Oblivion*, 99–103, 116; USAF Historical Study 85, 286; IX Air Defense Command, 78–79; History, 352d Fighter Group, January 1945 [AFHRC-Gp-352-Hi]; History, 366th Fighter Group, January 1945 [AFHRC-Gp-366-Hi].

38. US Army Air Defense School, "Air Defense," 2:158–63; Welborn, "Over-all Effectiveness," 9, 29.

39. Note nos. 30 and 33, US Army, Antiaircraft Artillery [L]; US Air Forces in Europe, "Air Staff Post Hostilities Intelligence Requirements on German Air Defenses," report, vol. 1, sec. 4, 14 September 1945, 17 [AFHRC-519.601B-4].

40. Walter Grabman, "German Air Force Air Operations Defense: 1933–1945," circa 1957, 3, 18, 40a, 81, 83–84 [AFHRC-K113.107-164]; D. von Renz, "The Development of German Antiaircraft Weapons and Equipment of all Types up to 1945," study, 1958, 102 [AFHRC-K113.107-194].

41. Ian V. Hogg, *German Artillery of World War II* (London: Arms and Armour, 1975), 162, 167; R. A. Devereux, "German Experience with Antiaircraft Artillery Guns in WWII," study, 19 July 1946 [AUL-M36686U]; US Air Forces in Europe, "Post Hostilities Investigation," 1:3 [AFHRC-519.601A-1].

42. Hogg, *German Artillery*, 170, 172; US Air Forces in Europe, "Post Hostilities Investigation," 1:5; Peter Chamberlain and Terry Gander, *Antiaircraft Guns* (New York: Arco Publishing, Inc., 1975), 22.

43. Hogg, *German Artillery*, 173–78; Chamberlain and Gander, *Antiaircraft Guns*, 23–24; US Air Forces in Europe, "Post Hostilities Investigation," 1:10, 22.

44. Matthew Cooper, *The German Air Force, 1933–1945* (London: Jane's Publishing Co. Ltd., 1981), 185; Samuel E. Morrison, *History of US Naval Operations in World War II*, vol. 9, *Sicily-Salerno-Anzio: January 1943–June 1944* (Boston, Mass.: Little, Brown and Co., 1954), 215–16; Albert N. Garland and Howard M. Smyth, *The US Army in World War II: The Mediterranean Theater of Operations, Sicily and the Surrender of Italy* (Washington, D.C.: Office of the Chief of Military History, 1965), 375, 379, 412; John Terraine, *A Time For Courage: The Royal Air Force in the European War, 1939–1945* (New York: Macmillan Publishing Co., Inc., 1985), 579.

45. Assistant Chief of Air Staff, Intelligence Historical Division,

*The Ploesti Mission of 1 August 1943*, USAF Historical Study 103 (Maxwell Field, Ala.: Historical Division, June 1944), 16, 50, 99 [AFHRC-101-103]; Report of Army Air Forces Evaluation Board "Ploesti," 15 December 1944, vol. 6:7–8 [AFHRC-138.5-12 VI]; Report of Mediterranean Allied Air Forces (MAAF), "Ploesti: Summary of Operations Results and Tactical Problems Involved in 24 Attacks Between 5 April–19 August 1944," 13 January 1945, 1–3 [AFHRC-628.424-1].

46. AAF Evaluation Board, "Ploesti," 2, 4, appendix E; MAAF, "Ploesti," 2; History, 1st Fighter Group, June 1944, 2 [AFHRC-Gp-1-Hi]; History, 82d Fighter Group, June 1944, 2 [AFHRC Gp-82-Hi].

47. MAAF, "Ploesti," 1–3; AAF Evaluation Board, "Ploesti," ii; Fifteenth Air Force, "The Air Battle of Ploesti," report, n.d., 83 [AFHRC-628.424-2].

48. Von Renz, "Development of German Antiaircraft Weapons," 380; US Air Forces in Europe, "Post Hostilities Investigation," 8:11; USSBS report, *European War*, no. 115, "Ammoniakwerke Merseburg, G.m.b.H., Leuna, Germany," March 1947, 7–16, 21 [AUL-940.53U58re #115]; Frank W. Anderson, Jr., "German Antiaircraft Defenses in World War II,"*Air University Quarterly Review*, Spring 1954, 85.

49. US Air Forces in Europe, "Post Hostilities Investigation," 5:2; Report of Army Air Forces Evaluation Board European Theater of Operations, "Flak Defenses of Strategic Targets in Southern Germany," 20 January 1945, 25 [AFHRC-138.4-74]; Report of Mediterranean Allied Air Forces, "Flak and MAAF," 7 May 1945, 9 [AFHRC-622.3813-1]; Report of Fifteenth Air Force, "Comparative Analysis of Altitudes and Flak Experienced During the Attacks on Vienna 7 and 8 February 1945," 3–4 [AFHRC-670.813-5].

50. Von Renz, "Development of German Antiaircraft Weapons," 257; US Air Forces in Europe, "Post Hostilities Investigation," 7:7, 37; USSBS, *The German Flak Effort Throughout the War*, 13 August 1945, 16, 19 [AFHRC-137.310-4]; Johannes Mix, "The Significance of Anti-Aircraft Artillery and the Fighter Arm at the End of the War," *Flugwehr und Technik*, February–March 1950, 5, 10; Thomas I. Edwards and Murray A. Geisler, "Estimate of Effect on Eighth Air Force Operations if German Antiaircraft Defenses Had Used Proximity-Fuzed (VT) Ammunition," report no. 1, Operations Analysis, AC/AS-3, Headquarters Army Air Forces, Washington, D.C., 15 February 1947 [AFHRC-143.504-1]; US Air Forces in Europe, Walter von Axthelm, "Interrogation Report," vol. 12, area 1945, 26–27.

51. Von Renz, "Development of German Antiaircraft Weapons,"

340–43, 353; Ernst Klee and Otto Merk, *The Birth of the Missile: The Secret of Peenemünde* (New York: E. P. Dutton, 1965), 65.

52. Von Renz, "Development of German Antiaircraft Weapons," 355; von Axthelm, 24; US Air Forces in Europe, "Post Hostilities Investigation," 3:43–44.

53. Von Renz, "Development of German Antiaircraft Weapons," 357; US Air Forces in Europe, "Post Hostilities Investigation," vol. 12, fig. 61, 8, 9, vol. 1:23; Willy Ley, *Rockets, Missiles & Space Travel* (New York: Viking Press, 1951), 222, 223, 393.

54. Von Renz, "Development of German Antiaircraft Weapons," 362; US Air Forces in Europe, "Post Hostilities Investigation," 12:7, fig. 60; Military Intelligence Division, "Handbook on Guided Missiles: Germany and Japan," no. 461, 1946 (hereafter cited as MID 461); Klee and Merk, 68, 86; Ley, 395.

55. MID 461; US Air Forces in Europe, "Post Hostilities Investigation," 12:8, fig. 61; Ley, 223, 394.

56. Von Renz, "Development of German Antiaircraft Weapons," 362; US Air Forces in Europe, "Post Hostilities Investigation," 8:10, 12:7, fig. 61; MID 461; Ley, 395; Klee and Merk, 68.

57. The V-1 was almost 47 feet long and had a takeoff weight of 28,229 pounds. Ley, 390, 393.

58. Ibid.; US Air Forces in Europe, "Post Hostilities Investigation," 12:6; Klee and Merk, 66–68, 125.

59. USSBS, *German Flak*, 2, 5, 19; von Axthelm, Interrogation Report, 44; Mix, "Significance of Anti-Aircraft Artillery," 22.

60. *Army Air Forces Statistical Digest: World War II* (Washington, D.C.: Office of Statistical Control, December 1945), 255–56.

61. Thomas Edwards and Murray Gelster, "The Causes of Bombing Errors as Determined From Analysis of Eighth Air Force Combat Operations," report no. 3, Operations Analysis, AC/AS-3, Headquarters Army Air Forces, 15 July 1947, 3, 19 [AFHRC-143.504-3]; "Report by Mr Butt to Bomber Command on His Examination of Night Photographs, 18 August 1941," in Charles Webster and Noble Frankland, *The Strategic Air War Against Germany, 1939–1945*, vol. 4, *Annexes and Appendices* (London: Her Majesty's Stationery Office, 1961); Minutes of the Flak Conference conducted at Headquarters United States Strategic Air Forces in Europe (A-2), London, 1–11 June 1945 [AFHRC-519.646-2].

62. USSBS, "German Flak," 19; Harry Smith, "Flak Evasion," *Electronic Warfare*, April–May 1970, 18–19, 36; Eighth Air Force, "Reduction of Losses and Battle Damage," operational research report, 12 February 1944, 15, 50 [AFHRC-520.310-6].

63. Eighth Air Force, "Special Report of Operations in Support of

First Allied Airborne Army: 17–26 September 1944," 9–13 [AFHRC-520.310 VII].

64. Albert H. Davis et al., *56th Fighter Group in World War II* (Washington, D.C.: Infantry Journal Press, 1948), 79–81; History, 56th Fighter Group, summary report, 18 September 1944 [AFHRC-Gp-56-Hi]; John B. B. Tussell, Jr., "Flak versus Fighters," *The Coast Artillery Journal*, July–August 1946, 43; Eighth Air Force, "Special Report of Operations in Support of First Allied Airborne Army," 18.

65. Eighth Air Force, "Special Report of Operations in Support of First Allied Airborne Army," 43–44.

66. Headquarters US Strategic Air Forces in Europe, Office of the Director of Operations, "Neutralizing German Anti-Aircraft Defenses," study, 14 November 1944, 1–3 [AFHRC-519.525-1].

67. Elwood R. Quesada, "Effect of Antiaircraft Artillery on IX Tactical Air Command Operations," *The Coast Artillery Journal*, September–October 1946, 29.

68. Ibid.; Historical Division, Department of the Army, *Utah Beach to Cherbourg (6 June–27 June 1944)* (Washington, D.C.: Government Printing Office, 1947), 171–73.

69. Joint report no. 4, "German Flak and Allied Counter-Flak Measures in Operation Varsity" [W-Operational Research in Northwest Europe, MID 479]; "History of Air Defense," *Air Defense Magazine*, April–June 1977, 22. Little information is available on Soviet flak defenses. James Hansen writes in "The Development of Soviet Tactical Air Defenses," *International Defense Review*, May 1981, 53, that the Soviets increased their antiaircraft weapon by a factor of eight between 1941 and 1945. He asserts that the Soviets credit flak with 40 percent of their 7,000 aircraft claims.

70. Kirkpatrick, *Archie in the AEF*, 179, 93, 100.

71. Garland and Smyth, *The US Army in World War II*, 175–82; Charles R. Shrader, "Amicicide: The Problems of Friendly Fire in Modern War" (Paper, Combat Studies Institute, Fort Leavenworth, Kans., 1982), 67–68.

72. Shrader, "Amicicide," 69.

73. Aircraft Identifiers Gree, 2757, and Brentrall, 2759, to commandant, subject: "Aircraft Identifiers Aboard Merchant Ships, 9 June 1944"; "Analysis of Reports Concerning the Engagement of Friendly Aircraft by Our Own Ground or Shipborne Forces and Also All Reports Covering the Engagement of Our Own Ground Forces by Friendly Aircraft," Item No. 4, "Attacks on Friendly Aircraft by Ground and Naval Forces," Annex A to 21 Army Group/225/Ops, 29 July 1944; History, 65th Fighter Wing, "Light, Intense and Accurate: US Eighth Air Force Strategic Fighters vs. German Flak in the ETO,"

89 [AFHRC-Wg-65-Su-Re]; US Army Air Defense School, "Air Defense," 2:38, 169; War Diary of Brig Gen Richard E. Nugent, November 1944, 12 [AFHRC-533.13-2]; Shrader, "Amicicide," 34, 45, 66, 70; David Mets, *Master of Airpower* (Novato, Calif.: Presidio Press, n.d.), 268.

74. Report of General Board, US Forces, European Theater, "Antiaircraft Artillery Techniques," 10.

75. US Fleet, Antiaircraft Action Summary—October 1944, Information Bulletin no. 27, 9-2 [AFHRC-180.102-27].

76. Shrader, "Amicicide," 70–71.

77. Buford Rowland and William B. Boyd, *US Navy Bureau of Ordnance in World War II* (Washington, D.C.: Government Printing Office, n.d.), 219–20, 231, 235, 238, 245–47, 258, 266; Robert Sherrod, *History of Marine Corps Aviation in World War II* (Washington, D.C.: Combat Forces, 1952), 401.

78. Rowland and Boyd, *US Navy Bureau*, 221–34, 266; Chamberlain and Gander, *Antiaircraft Guns*, 40; Information Bulletin no. 27, 1–5.

79. Rowland and Boyd, *US Navy Bureau*, 220, 266, 283, 286; US Fleet, Information Bulletin no. 27, 1–5.

80. US Army Air Defense School, "Air Defense," 2:192.

81. Ibid., 197–98; Chamberlain and Gander, *Antiaircraft Guns*, 34; Report of General Headquarters, United States Army Forces Pacific, Antiaircraft Research Board, "Survey of Japanese Antiaircraft Artillery," 3–5, 59, 65, 66, 72 [L]; United States Pacific Fleet and Pacific Ocean Areas Flak Intelligence Memorandum Number 4, "Japanese Antiaircraft Materiel," 11 April 1945 [NHC].

82. *AAF Statistical Digest*, 221–27, 255–61; A. H. Peterson, R. G. Tuck, and D. P. Wilkinson, "Aircraft Vulnerability in World War II" (Working paper, Rand Corporation, Santa Monica, Calif., rev. 12 July 1950), table 8 [AUL-M30352-9]; Office of Information, Document 3 May 1967 in "Korean Combat Statistics for Three-Year Period," 19 June 1953 [NHC].

83. US Army Air Defense School, "Air Defense," 2:293; AAA Research Board, "Survey of Japanese AAA," 192; Chief of Naval Operations, Air Intelligence Group, Flak Information Bulletin no. 10, June 1945, 28 [AFHRC-180.104-10].

84. *AAF Statistical Digest*, 226, 261; Air Intelligence Report no. 8, 15–17; Twentieth Air Force, "Flak Damage on Various Types of Missions," and "Final Analysis of Flak Loss and Damage for Operations Against Japan," Air Intelligence Report, vol. 1, nos. 26–27, November–December 1945, 3–7 [AFHRC-760.607].

85. Flak downed a number of the top aces. In World War I, ground fire downed the top ace, the Red Baron, Manfred von Richthofen (80

credits). In World War II, the leading American ace in Europe, Francis S. Gabreski (28 credits), crashed while attacking an airfield; US flak killed George E. Preddy, Jr. (26.8 credits); while German flak downed others such as Hubert Zemke (17.8 credits) and Duane W. Beeson (17.3 credits). Japanese AAA killed Robert Hanson (25 credits), the third-ranking Marine ace. Flak also got two of the top British aces, Brendan Finucane (32 credits) and Robert Tuck (29 credits).

## CHAPTER 2

# THE POSTWAR YEARS, 1945-65

Rapid demobilization of the American military followed the war's end. As the magnificent, if not lavish, US war machine disappeared, not much was left in its place. Americans thought little of either war or the military as they engaged in their peacetime pursuits, thereby leaving the US armed forces with minimal tangible strength. The two driving forces of national policy during this period were tight budgets and trust in the atomic bomb. America based its defense on confidence in overall American superiority and distance, but most of all, on faith in the bomb. Specifically, the United States had the atomic bomb and a means to deliver it; the Soviet Union had neither.

The offensive problem seemed relatively simple to American airmen, compared with what they had just faced in World War II. Instead of vast formations of aircraft, now only one aircraft (with the equivalent bomb load of thousands of World War II bombers) needed to be employed. The penetration problem also appeared easier; for in contrast to dense German defenses covering a target area of hundreds of miles, the Soviet Union had relatively sparse defenses to cover thousands of miles. Another factor favoring the offensive was that jet aircraft offered performance superior to that of World War II aircraft. Probably most important, instead of opposing a foe with essentially equivalent technology and the potential to develop superior technology, the United States now faced a nation considered to be years and years behind the United States. The most serious problems for the American airmen appeared to be those of range and basing.

American technological superiority also provided the key to the airmen's defensive problems. Few airmen thought the Soviets would get nuclear weapons in short order. In addition, they believed the Soviets could not quickly master the problem of weapons delivery over intercontinental distances.

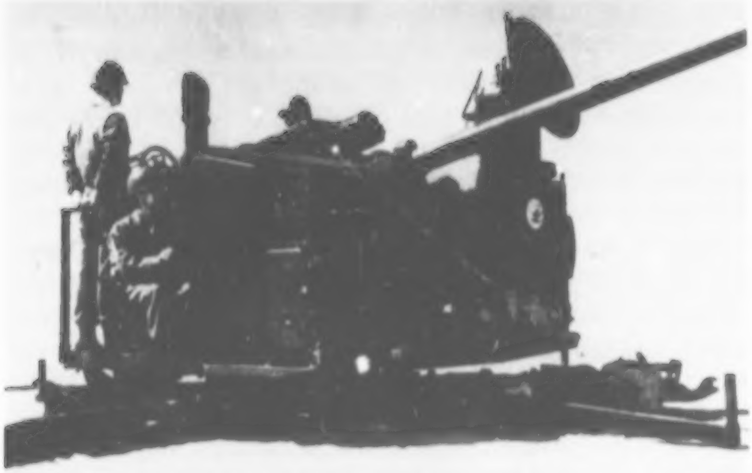
American antiaircraft (AA) defenses shrank along with the entire American military. By late 1947 the US Army had only two battalions of antiaircraft artillery. Active American air defense took three directions in the late 1940s. The most expensive of these, aircraft, falls beyond the scope of this study. The other two directions were antiaircraft guns and missiles.

The postwar story of antiaircraft guns is primarily that of phaseout. At first, postwar budget cuts and the existence of World War II equipment disguised the gun's fate. The United States did develop one new antiaircraft artillery piece in this period, the 75-mm Sky Sweeper (fig. 38).* The pilot model appeared in 1948, and the weapon went into service in March 1953.[1]

Antiaircraft guns proved useful in the Korean War, despite the almost utter lack of air opposition, primarily as ground-support arms. In the military buildup prompted by the Korean War, the Army deployed 66 battalions of AA guns for continental defense. Nevertheless, following tests in 1955, the Army dropped its quadruple .50-caliber guns. The dual 40-mm guns lingered on in service into the early 1960s before being transferred from the Regular Army into the National Guard. The Hawk (homing all-the-way killer) missile took over the job of the 40-mms and the 75-mm Sky Sweeper.[2]

---

*It could fire at a rate of 45 to 55 rounds per minute (rpm) with a muzzle velocity of 2,825 feet per second (fps) and could reach a vertical altitude of 18,600 feet.



*(Photo Credit: US Army Air Defense Artillery Museum)*

Figure 38. 75-mm Sky Sweeper.

## The Korean War

The Korean War was far different from what the planners anticipated—unlike their experience of World War II or their forecasts of World War III. In the Korean War, American airmen did not face dense, technically advanced, ground-based antiaircraft defenses or an extensive air-to-air threat; nor did they conduct strategic nuclear operations against a major power. Instead, both sides limited the Korean War politically and militarily. The United States (through the United Nations) fought a second-rate and third-rate power, albeit with major power backing, without nuclear weapons and without strategic targets. American airmen waged an air war primarily of close air support (CAS) and interdiction against weak and obsolete ground defenses. American flyers engaged modern fighters, but in action geographically remote from the main theater of operations.

Compared with the defenses the Allies encountered in World War II, Communist ground-based defenses in Korea proved weak in numbers and technology. American intelligence estimated their foes possessed only 252 heavy flak pieces and 673 light pieces in May 1951, increasing and peaking at 786 heavy and 1,672 light guns in January through February 1953. These totals barely exceeded the numbers that the Germans deployed around some of their key targets late in World War II. The equipment itself was vintage World War II. Although the airmen faced a few 76-mm guns, the principal Communist heavy flak weapon was the Soviet 85-mm Model 1939 gun capable of firing 15 to 20 20.1-pound shells per minute at 2,625 fps to an effective ceiling of 27,000 feet. Later, the Communists supplemented these guns with 85-mm Model 1944 guns that had an additional muzzle velocity of 325 fps and an increased altitude capability of 4,000 feet. In the later stages of the war, some of these guns were controlled by radar. The main light flak piece was the 37-mm automatic weapon. The Communists also used large numbers of 12.7-mm machine guns. Beginning in October 1951 Allied airmen reported unguided flak rockets that reached 10,560 feet. But there are no indications of any successes with this weapon, and reports of their firing faded out by December 1952.[3]

How effective was Communist flak in the Korean War? It did not prevent air operations but it did make them more expensive. Hostile fire and operations at increased altitudes to counter flak reduced bombing accuracy. The US Air Force estimated that dive-bombing accuracy declined from a 75-foot CEP* in 1951 to 219 feet in 1953,[4] which meant that more sorties were required to destroy a target. American losses to enemy action totaled 1,230 Air Force, Marine Corps, and Navy aircraft, all but 143 were claimed by ground fire.[5] US Air Force losses to flak on a sortie basis declined during the course of the war from a rate of .18 percent in 1950 to .07 percent in 1953. Overall American (Air Force, Marine Corps, and Navy) combat losses of 1,230 aircraft on 736,439 sorties amounted to a rate of .17 percent.[6]*

---

*Circular error probable—An indicator of the delivery accuracy of a weapon system, used as a factor in determining probable damage to a target. It is the radius of a circle within which half of a missile's projectiles are expected to fall.

A further breakdown reveals that US Air Force losses were not evenly spread—fighter-bombers sustained 58 percent of aircraft losses, although they logged only 36 percent of sorties, and jets suffered less than did propeller-powered aircraft. The jets took fewer hits because they operated at higher speeds and altitudes than did the propeller aircraft. The Navy's gull-wing F4U Corsair of World War II took hits at twice the rate as did the straight-wing jet F9F and thus was considered 75 percent more vulnerable. Similarly, the US Air Force's famous propeller-powered F-51 Mustang (fig. 39) was much more vulnerable than the jet-powered

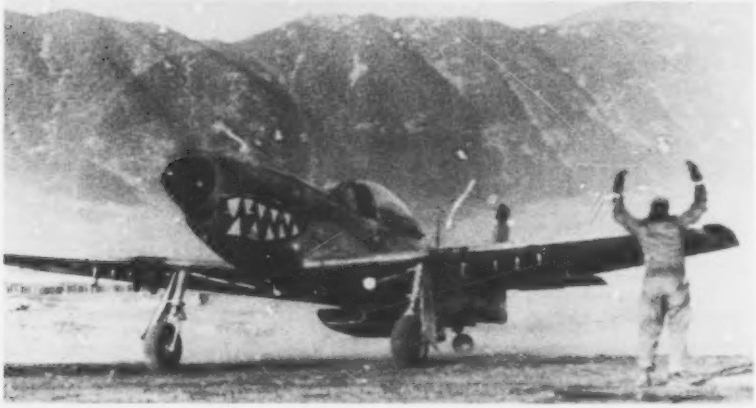


**Figure 39. An air base in Korea. A typical scene at this Fifth Air Force's 18th Fighter Bomber Wing is the crew chief guiding the F-51 Mustang fighters to the desired parking area, after the completion of the mission in 1951.**

---

*In addition to the 689 Air Force and 541 Marine Corps/Navy combat losses to enemy action, there were 776 Air Force and 588 Marine Corps/Navy losses on operations not due to enemy action.

best copy available

F-80 Shooting Star (fig. 40). In the period July through November 1950, the Mustang had a loss rate of 1.9 percent* compared with the Shooting Star's loss rate of .74 percent.[8] The Air Force assessed the loss rate of prop aircraft to be triple that of jet aircraft. A breakdown of losses in the month of August 1952 indicated that light flak was the main problem. In that month flak destroyed 14 Fifth Air Force aircraft and damaged 153 others. The Air Force credited light flak with 79 percent of the downed aircraft and 45 percent of the damaged aircraft, small arms with 7 and 52 percent, and heavy flak with 14 and 3 percent.[9]

In early 1952 American losses to ground fire prompted remedial action. One factor in the equation involved how close the aircraft flew to the ground; but despite the wealth

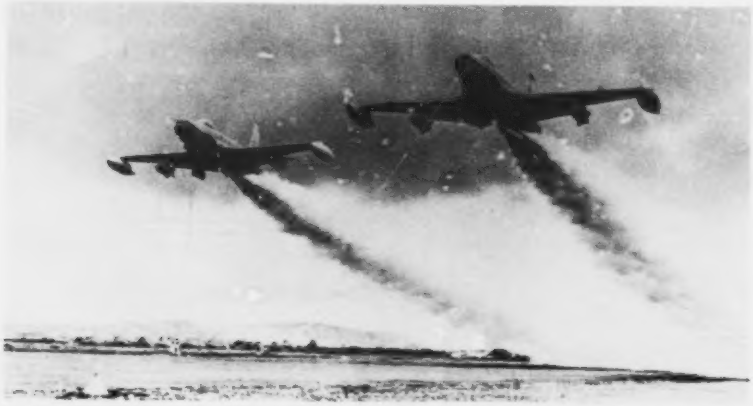


**Figure 40. Fifth Air Force, Korea. Two US Air Force F-80 Shooting Star jets use jet-assisted takeoff (JATO) tubes to speed them into the air in 1952 with a heavy armament load destined for Communist transportation targets.**

---

*The US Air Force knew the F-51 was vulnerable to ground fire because of its liquid-cooled engine and air scoop beneath the fuselage. One World War II study of fighters in the European theater indicated that the P-51 (as it was then designated) was three times as vulnerable to the flak as was the P-47.[7] The author was told that the decision to employ the F-51, not the more rugged P-47, in Korea was based primarily on the availability of parts.

of data from World War II, it apparently took an operations analysis study in early 1952 to bring this fact to the attention of the decisionmakers. One study indicated that in the first four months of 1952, Fifth Air Force aircraft sustained half of their ground-fire hits below 2,500 feet.[10] Following a Communist flak success on 10 July 1952 the Fifth Air Force ordered a minimum recovery altitude of 3,000 feet. Similarly, in reaction to B-26 (fig. 41) losses north of the battle lines, the Fifth Air Force established a 4,000-foot attack altitude for light bombers with only selected crews permitted to operate lower. In August, the Navy adopted a 3,000-foot minimum pullout altitude. This policy resulted in a decrease in American aircraft losses.[11] In the first four months of 1952, Fifth Air Force studies concluded that ground fire destroyed or damaged 21.6 aircraft per 1,000 sorties; whereas in the period 1 September 1952 through 30 April 1953, the rate decreased to 11.1 aircraft per 1,000 sorties. Analysts attributed 19 percent of the decrease to

**Figure 41.** **A tight formation of B-26 light bombers of the Fifth Air Force's 452d Bomb Wing do some cloud hopping as they head home to their base in Japan. They have just completed a devastating low-level sweep on enemy Communist targets with bomb rockets, napalm, and .50-caliber fire in early 1951.**

the altitude policy and a further 32 percent to target diversification. As a counterpoint, the Fifth Air Force removed the altitude restriction for two weeks in June 1953 and suffered the consequences. During that month the unit suffered its highest 1953 monthly losses—18 aircraft to ground fire, including 12 of its newest fighter-bombers, the F-86F.[12]

Another policy adopted by the Fifth Air Force in June 1952 limited the time over the target. It mandated that, with the exception of air defense and F4U aircraft, pilots were to make only one run over a target for each type of external ordnance carried; and it forbade strafing. In August 1952 the Fifth Air Force modified the policy by restricting general support and interdiction mission to one pass and close air support to two passes.[13]

American airmen also employed more direct methods against enemy antiaircraft artillery. Apparently, the Marines tried flak suppression tactics in late 1951 or early 1952—Marine spotter aircraft could temporarily divert strike aircraft to hit flak positions. In June 1952 the Marines published a procedure that put suppressive fire on flak positions 30 seconds before their aircraft began their dive-bombing runs. Thereafter, Marine aircraft losses dropped.[14]

At about the same time, the Army and Air Force adopted similar tactics, although there is no indication that there was any coordination among the three services. Prior to July 1952 the Army and Air Force operated under procedures established in plan NEGAT, which curtailed friendly artillery fire during an air strike and restricted almost all artillery fire within a 2,500-yard radius of the target. Friendly guns would mark targets with smoke or white phosphorous shells and, between the time the spotter aircraft left the area and the fighter-bombers arrived, fire against known antiaircraft positions. Prompted by the loss of two C-119s (fig. 42) to American artillery fire in June 1951, the policy emphasized safety from "friendly" fire. But the policy satisfied neither airmen nor soldiers and

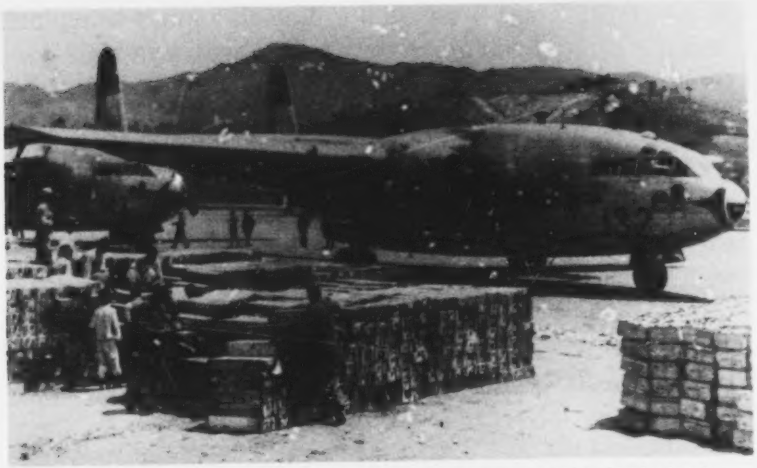


**Figure 42. US Air Force C-119s were one of the logistical workhorses of the Korean War.**

became even less acceptable to both as the Communists burrowed deeper into the ground, brought up increasing flak pieces, and learned American air support procedures. Not only did fighter-bomber losses remain high, but the procedures left a large area along the front without artillery support for eight to 45 minutes during the air strike. Following a meeting between the two services in July 1952, the Army eased the restriction on artillery fire to a minimum time, although it retained prohibitions on the use of proximity-fuzed fire and high-angle fire when aircraft were in the area. The airmen now saw that the danger from enemy guns exceeded the danger from "friendly" guns.

In their next step, the Americans actively engaged the flak. On 6 August 1952 the Air Force and Army produced plan SUPPRESS, which set out procedures to neutralize suspected and known antiaircraft positions. While retaining the July artillery restrictions, SUPPRESS permitted the fighter-bomber pilots to either accept or reject artillery support. The gunners would hit suspected positions with proximity-fuzed fire before the strike and then signal the end of proximity-fuzed fire with a radio call and a white phosphorous or colored smoke round. The artillery would continue the bombardment with impact-fuzed ammunition. During a one-month experiment with these procedures in IX Corps (25 September through 25 October 1952), the US Air Force lost only one aircraft on 1,816 CAS sorties, compared with planning figures of one loss for every 380 CAS sorties. (Army artillery fired 679,000 rounds in connection with the air strikes.) This marked decline in aircraft losses came despite the tripling of Communist flak guns in the area facing the IX Corps.

The Eighth Army and Fifth Air Force also adopted the policy, which became effective on 2 December 1952. Under the slightly modified procedures, a light aircraft (a T-6 Mosquito) led the fighter-bombers into the area, marked the target, and after the fighter-bomber pilots identified the target, called in artillery fire (fig. 43). All known antiaircraft guns within 2,500 yards of the target would be hit first with proximity-fuzed shells and finally with a white phosphorous or colored smoke round. The barrage continued with impact-fuzed shells for three minutes as the aircraft attacked. Despite problems such as fighter-bomber pilots not always being ready to exploit the suppression fire, and increased numbers of Communist flak guns, fighter-bomber losses remained acceptable. CAS sorties per fighter-bomber loss rose from 917 in December 1952 to 1,285 in January 1953, to 2,981 in late March and early April, then dropped to 1,281 in June and, finally, rose to about 1,515 in July.[15]

Clearly, the Americans had forgotten much of their experience with flak in World War II. The airmen's flak countermeasures came as a response to losses and not from any study of the situation or from previous experience. Not until late in the war, after almost two years, did the Army and Air Force establish effective coordinated tactics. No one attempted to coordinate, or to compare notes, with the Marines or Navy. But even having done all of this, the question is how much did the American airmen learn. In

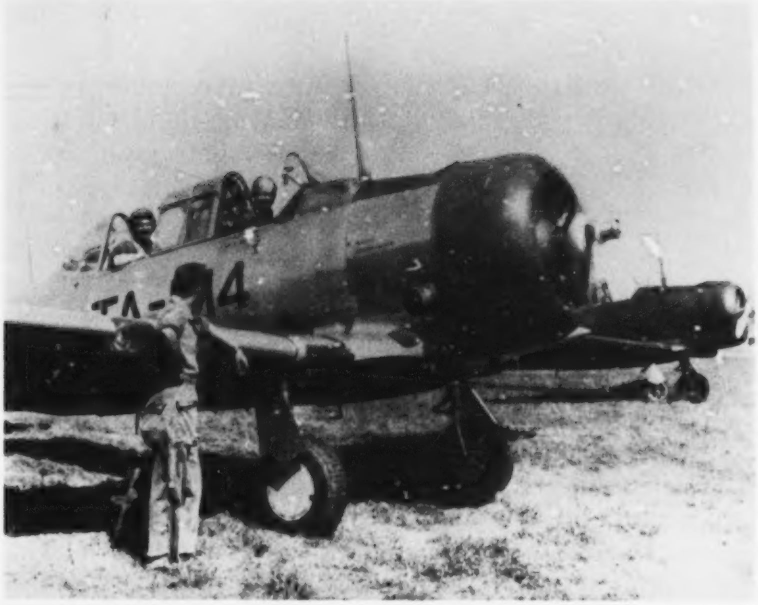


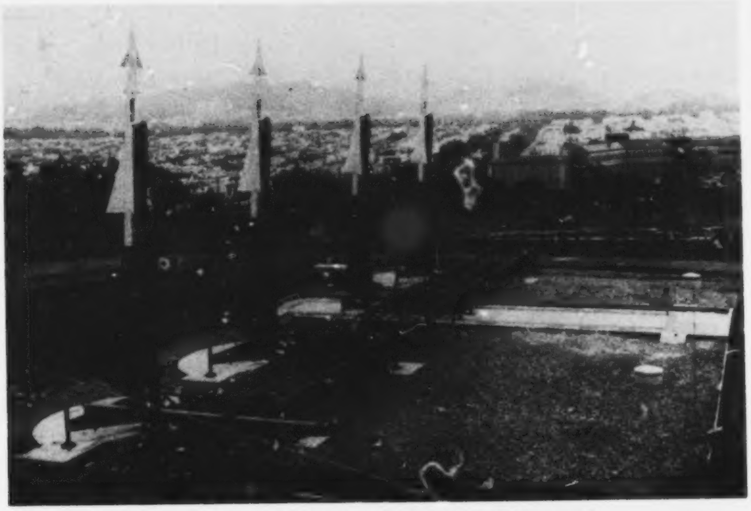
**Figure 43.** After training more pilots than any other plane, the old North American T-6 has finally gone to war herself. Needed in Korea was a sturdy, dependable, fairly fast spotting plane to guide Far Eastern Air Force and Navy fighter pilots to North Korean targets in minimum time.

a study of the lessons from the air war in Korea, the US Air Force did not even mention enemy flak among the almost 100 items, but included such areas as heckling attacks, rescue operations, and Communist passive defense. Surely flak was more important and more costly to the US Air Force than that. It is this attitude that led Air Force Chief of Staff Thomas D. White to tell his top commanders in October 1957 that the US Air Force had never respected flak but that it could no longer ignore it. He insisted that the airmen find out more about antiaircraft defenses, and find it out quickly.[16]

## Antiaircraft Missiles

At the same time US military forces were enduring the post-World War II reduction and then the trauma and frustrating limited war in Korea, a major technological development was evolving. This device, which would greatly improve air defense and radically change air warfare, was of course the surface-to-air missile (SAM). A number of countries attempted to follow up on the German efforts in the field, but for 20 years these first-generation missiles were notable more for their promise than for their performance. The large and unwieldy missiles demonstrated limited mobility. Initially, they used liquid fuel with its problems of handling, reliability, reaction time, and storage. The early missiles were guided by command systems in which one radar unit acquired and tracked the target, a second tracked the missile, and a computer made missile corrections to ensure interception. Although this awkward system could down aircraft flying at relatively high altitudes, steady courses, and moderate speeds, it had little ability to kill fast-moving, low-flying, maneuvering targets. (It must be remembered, however, that air defenders saw formations of high-flying aircraft as the threat.) The command guidance system was also vulnerable to electronic countermeasures.

A number of projects emerged from American designers.[17] The US Army sponsored the widest variety of missiles. These missiles can probably best be divided generically into three families based on the missile's mobility: large, immobile SAMs; mobile missiles; and manportable systems. The earliest of these Army projects was the Nike family, begun in 1945 by Bell Laboratories. The first of these, the Nike Ajax (fig. 44), stood 34 feet high and weighed 2,455 pounds with its booster (21 feet and 1,150 pounds without it). It carried a 300-pound warhead at Mach 2.25 to a maximum slant range of 25 miles and an altitude of 60,000 feet. Ajax became the first operational

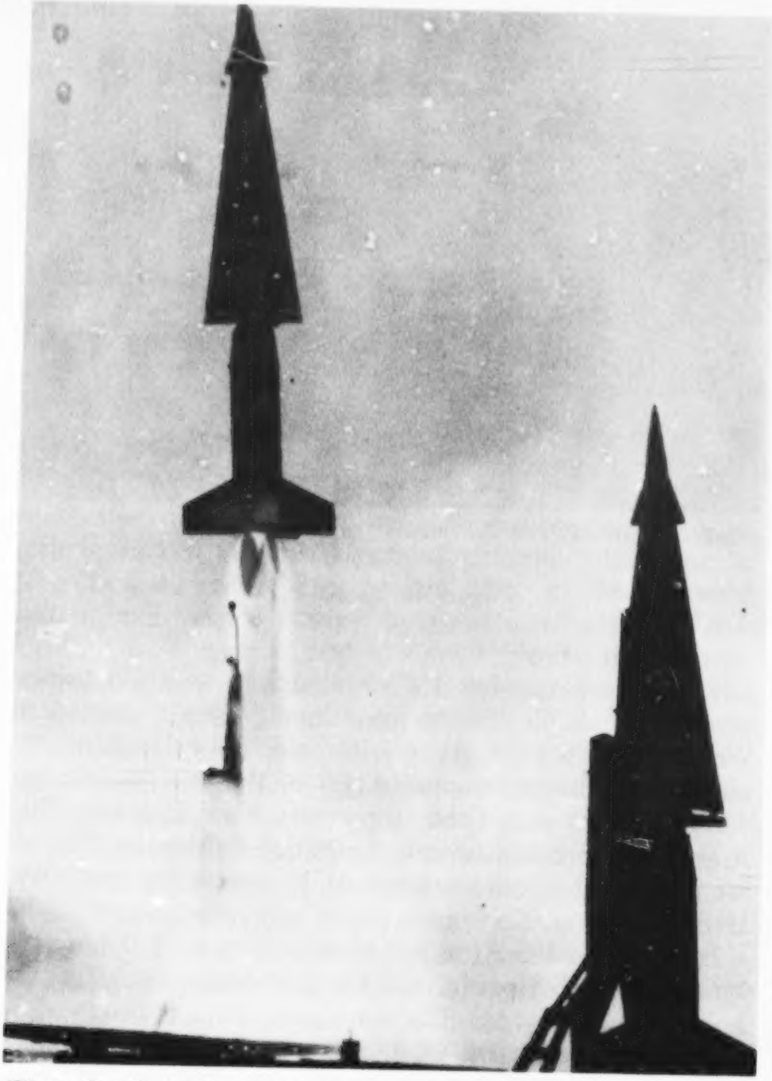


***(Photo Credit: US Army Air Defense Artillery Museum)***

**Figure 44. Nike Ajax.**

US SAM in December 1953 and served with US forces overseas and with at least five friendly foreign countries. Western Electric, the prime contractor (Douglas built the airframe), delivered about 15,000 of the missiles. About 5,500 of them were fired, apparently none in anger. The Ajax program cost just over $1 billion before the United States phased it out in favor of its successor, the Nike Hercules.

In 1953 the US Army's Ordnance Corps, Bell Laboratories, Western Electric, and Douglas began work on the Nike Hercules (fig. 45). The same basic technology was used on the Hercules as was used on the Ajax, although the former was somewhat larger (measuring 41.5 feet and weighing about 10,400 pounds with its booster) and used solid propellants. Hercules performed better than the Ajax, carrying a 119-pound warhead to a maximum slant range of 80 miles at Mach 3.65 and an altitude over 150,000 feet. Hercules

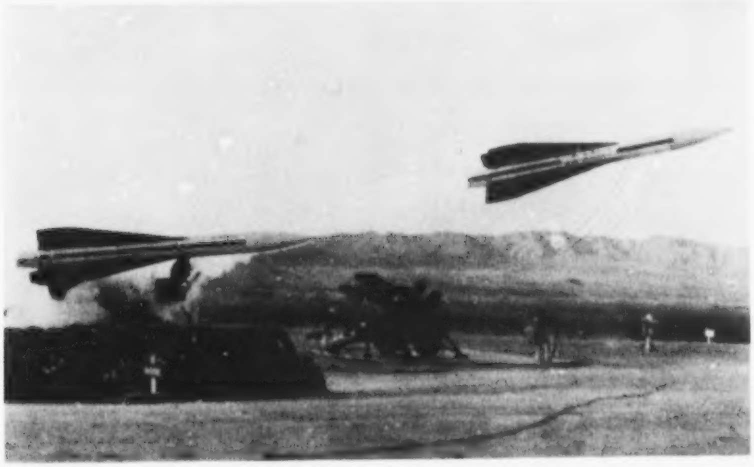


*(Photo Credit: US Army Air Defense Artillery Museum)*

**Figure 45. Nike Hercules.**

became operational in July 1958, when it began to replace the 58 Ajax battalions. One demonstration of the missile's capability came in September 1960 when one Hercules intercepted another flying at 100,000 feet and 30 miles from its launch. The United States built over 9,000 Hercules missiles at a program cost of about $1.9 billion.

A second family of missiles was somewhat smaller and much more mobile. In March 1953 Raytheon began development of the Hawk (fig. 46). It went into production in 1957 and into operation in July 1959. Shipped to Israel in 1964, the Hawk downed its first hostile aircraft, a MiG-21, in May 1969.[18] Hawk measured 16.5 feet in length and weighed about 1,300 pounds at launch, and therefore it was easy to transport. Guided by a continuous-wave semiactive radar homer (rather than the more easily jammed pulse radar), it carried a 163-pound warhead at Mach 2.2 to a slant range of 22 miles and an altitude of 40,000 feet. The Hawk program cost about $1 billion ($969 million) for just

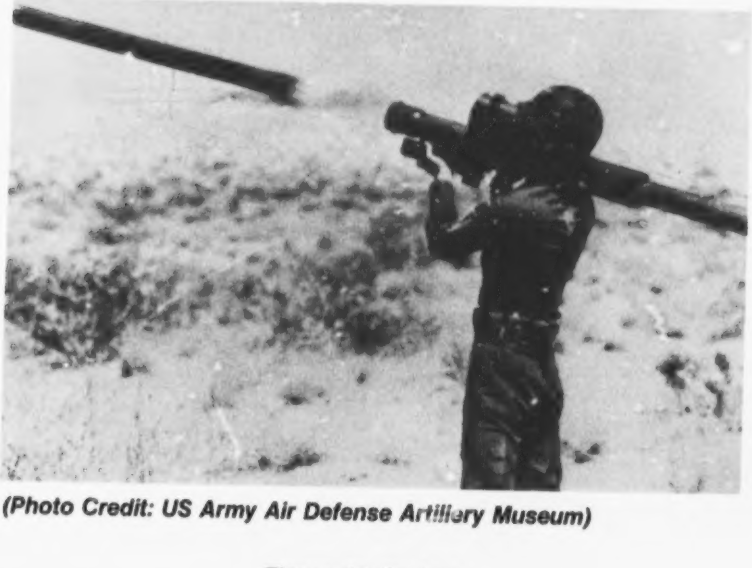


***(Photo Credit: US Army Air Defense Artillery Museum)***

**Figure 46. Hawk.**

over 13,000 missiles. The most notable aspect of the Hawk, however, is its adaptability. It has been modified, improved, and fielded in a number of advanced variants, some of which remain first-line equipment today.

The third family of antiaircraft missiles, man portable, began with a contract to Philco-Ford in 1958. The Redeye system (fig. 47), which looks like the World War II bazooka, is housed in a device serving as both container and launcher. The missile system measures about 3.5 feet in length, 2¾ inches in diameter, and weighs about 28 pounds. The operator acquires the target visually and fires when an aural signal indicates that the infrared homing system has locked onto the target. When fired, the missile is boosted 20 feet or so from the launcher before the rocket ignites, thus protecting the operator from rocket blast. Redeye travels at Mach 2.5 with a maximum range of 1.6 miles and 9,000-feet altitude. The missile went into production in 1964 and became operational that same year.



*(Photo Credit: US Army Air Defense Artillery Museum)*

**Figure 47. Redeye.**

The Navy also developed antiaircraft missiles. In December 1944 the chief of naval operations directed that work on the Bumblebee project begin at the Applied Physics Laboratory at Johns Hopkins University. This work resulted in the development of the Terrier and Talos missiles. The Convair Terrier measured 27 feet and weighed 3,000 pounds with its booster (14.8 feet and 1,100 pounds without). The Navy first fired the missile on September 1951 and put it into production the next year. It became the first US Navy SAM when it achieved operational status on the USS *Boston* in 1956. The Terrier carried a 200-pound warhead at Mach 2.5 to a slant range of 10 miles and an altitude of 40,000 feet. The United States built about 3,000 of these, and they served with the United States and two foreign navies.

The Bendix Talos also emerged from the 1944 Bumblebee project. It was larger than the Terrier (31.3 feet and 7,000 pounds with booster, 21 feet and 3,000 pounds without), which accounted for its better performance. Talos could carry a 300-pound warhead at Mach 2.5 over 60 miles slant range and reach an altitude of 87,000 feet. First fired in 1950, it became operational on the USS *Galveston* in 1959 (fig. 48). Bendix built almost 1,500 of these missiles (McDonnell built the airframe) at a program cost of $648 million.

The third naval missile was the Convair Tartar (fig. 49). It began, and was first fired, in 1956. Tartar went into production in 1958 and became operational three years later. The missile measured 15 feet in length and weighed 1,200 pounds. It could reach a slant range of over 10 miles, an altitude of 40,000 feet, and a speed of Mach 2.5. Convair built over 3,600 of these missiles at a cost of $495 million. It served with the United States and four foreign navies.

The Army's airmen also engaged in SAM work, even before they achieved independence. In April 1946 the AAF had three SAMs under development out of a total of 28

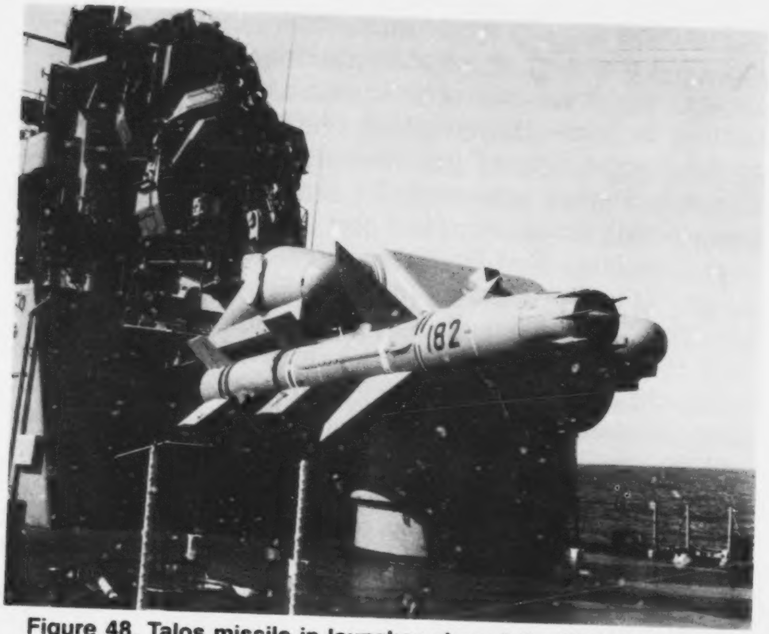


Figure 48. Talos missile in launcher aboard the USS *Galveston*.

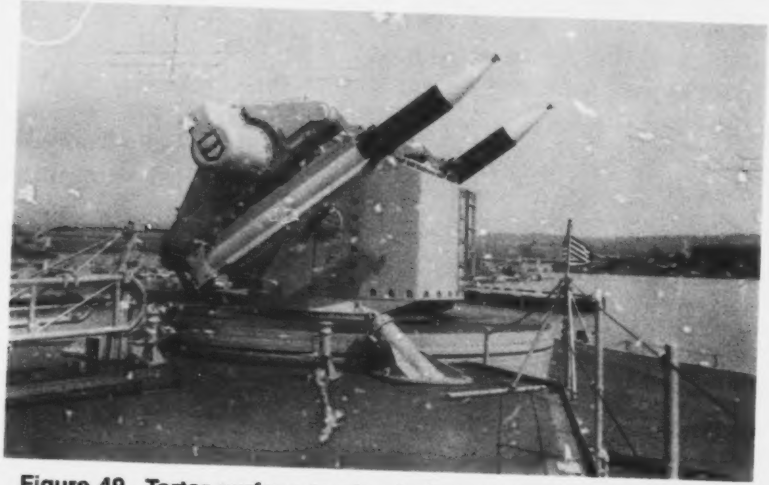
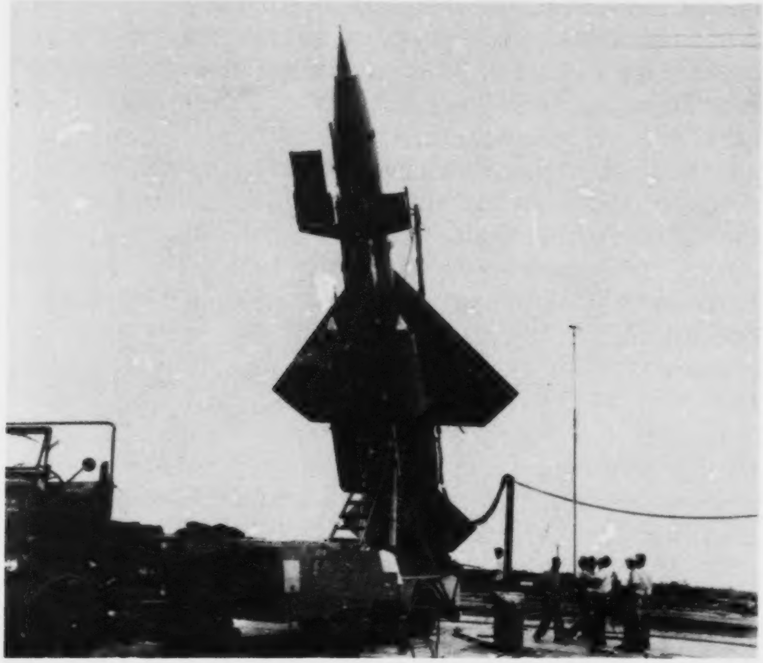


Figure 49. Tartar surface-to-air missile on Mark II mount aboard the USS *McCormick*.

missile projects. Boeing designed the ground-to-air pilotless aircraft (GAPA) to defend against aircraft, and the missile could reach a range of 35 miles and an altitude of 60,000 feet. The airmen test-fired about 100 of these missiles. Two other AAF projects were the University of Michigan's Wizard and General Electric's Thumper, both designed to reach ranges of 550 miles and altitudes of 500,000 feet. In 1947 the US Air Force relegated the two antiballistic missile projects to "prolonged study" status. By March 1948 the Air Force canceled the Thumper. Wizard continued as a study, but Boeing replaced the GAPA project with Bomarc (Boeing, University of Michigan Aeronautical Research Center) in 1949.[19]

Bomarc was essentially an unmanned aircraft. In fact, the airmen initially designated the missile XF-99 as it would any experimental fighter. The large (46.8-foot length, 18-foot span) and heavy (15,500 pound) missile was radio-controlled with an active radar-homing device. The US Air Force first fired the IM-99A (fig. 50), as it was redesignated, in 1952. In 1958 it completed an interception controlled 1,500 miles away (fig. 51). Two years later, it became operational. Bomarc could reach Mach 2.8, and it had a 250-mile slant range. The US Air Force first fired the "B" model, redesignated MIM-10B, in May 1959. Although 1.7 feet shorter than the "A" model, it weighed 532 pounds more and had greater performance; specifically, it could reach slant ranges of 440 miles. In its most memorable flight it intercepted a Regulus II target drone at 100,000 feet, 446 miles from its launch point. That July IM-99B became operational. In all, Boeing built 700 Bomarcs at a cost of $1.6 billion.

Other countries also engaged in designing, building, and testing SAMs. The British got their first SAM, Bloodhound, into service in 1958, the Thunderbird in 1960, and the Seaslug in 1962. These first-generation missiles had command guidance systems and were large in size (about 20



*(Photo Credit: Smithsonian Institution Photo No. 154042)*

**Figure 50. Boeing IM-99 Bomarc guided missile during erection prior to launching, 4 June 1953.**

feet in length).* The French worked on the PARCA and the MATRA R422-B; whereas the Swiss (Oerlikon) built the RSD 58, again all first-generation missiles. Meanwhile, the Soviets were also making progress with SAMs; but this must be put into the context of its testing in combat in Southeast Asia.

---

*British SAMs are addressed in chapter 4 in a discussion of the Falkland War.

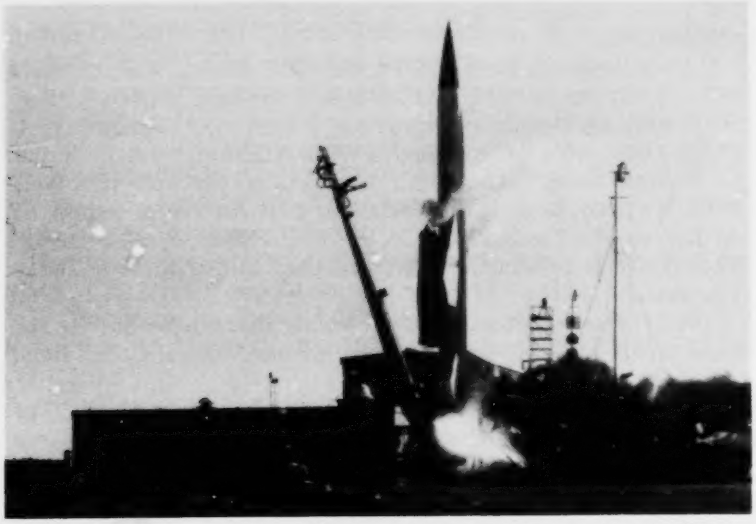


**Figure 51. Launch of an Air Force Bomarc interceptor missile at Cape Canaveral, Florida.**

## NOTES

1. Robert F. Futrell, *United States Air Force Operations in the Korean Conflict: 1 July 1952–27 July 1953*, USAF Historical Study 127 (Maxwell AFB, Ala.: USAF Historical Division, Air University, 1956), 87; US Army Air Defense School, "Air Defense: An Historical Analysis" (U), June 1965, vol. 3:30–33 [AUL-M39991-4]. (SECRET—Information extracted is unclassified.)

2. US Army Air Defense School, "Air Defense," 3:33–34; Max Rosenburg, "The Air Force and the National Guided Missile Program: 1944–1954," study, 1964, 36, 42 [AFHRC-K239.046-15]; Joseph Russo, "ADA in Retrospect," *Air Defense Trends*, July–September 1975, 12.

3. Futrell, Historical Study 127, 41, 43; Far East Air Forces Intelligence Roundup (12–18 January 1952), vol. 2:11–12; Far East Air Forces Intelligence Roundup (29 December 1951–4 January 1952), vol. 3:8 [AFHRC-K720.607A]; Andrew T. Soltys, "Enemy Antiaircraft Defenses in North Korea," *Air University Quarterly Review*, Spring 1954, 77–80.

4. Futrell, Historical Study 127, 165.

5. Ibid., 80.

6. Commander in chief, US Pacific Fleet, *Korean War: (25 June 1950–27 July 1953) US Pacific Fleet Operations*, chap. 3 [NHC]; "Carrier Operations Evaluation Report No. 6, Interim, 1 February 1953–27 July 1953," 44, 68, reproduced in William E. Hodge et al., "Theater Air Warfare Study" (Thesis, Air War College, Maxwell AFB, Ala., 1977), 39 [AUL-MS43117-H688t]; "Far East Air Forces Report on the Korean War," study, bk. 1:63, 82, 97 [AFSHRC-K720.04D]; US Navy Office of Information, "Korean Combat Statistics for Three-Year Period" [NHC].

7. A. H. Peterson et al., "Aircraft Vulnerability in World War II," Rand report RM-402, rev. July 1950 (Santa Monica, Calif.: Rand Corp.) fig. 13 [AUL-M30352-9].

8. Pacific Fleet Evaluation Group, research memorandum, "The Relative Risk to Anti-Aircraft Fire for Jet and Propeller Driven Ground Attack Aircraft in Korea," March 1952 [NHC]; Robert F. Futrell, *United States Air Force Operations in the Korean Conflict: 25 June–1 November 1950*, USAF Historical Study 71 (Maxwell AFB, Ala.: USAF Historical Division, Air University, 1952), 57 [AFHRC-101-71].

9. "FEAF Report on Korean War," 128; Fifth Air Force Intelligence Summary, 15 September 1952, 26 [AFHRC-K730.607].

10. Futrell, Historical Study 127, 152; Fifth Air Force, Operations Analysis Office, operations analysis memorandum, "A Survey of Fighter Bomber Tactics and Flak Losses," January 1952, 7 [AFHRC-K730.3101-1]; Pat Meid and James Yingling, *US Marine Corps Operations in Korea 1950–1953*, vol. 5, *Operations in West Korea* (Washington, D.C.: Historical Division, US Marine Corps, 1972), 64, 69.

11. Futrell, Historical Study 127, 152; Meid and Yingling, *West Korea*, 5:70.

12. Futrell, Historical Study 127, 152–53.

13. Meid and Yingling, *West Korea*, 5:70, 492n.

14. Ibid., 70–72.

15. Futrell, Historical Study 127, 219-22; History, Far East Air Forces, July–December 1952, vol. 1:58 [AFHRC-K720.01]; "FEAF Report on Korean War," 39.

16. Futrell, Historical Study 71, 116; "FEAF Report on Korean War," 39–41, 128–33; Memorandum by Thomas S. Power to Gen James B. Knapp, subject: Commanders' Conference, Patrick Air Force Base, 30 September–1 October, 4 October 1957, 2; "Strategic Air Command Participation in the Missile Program from March 1957

through December 1957," USAF Historical Study 70, vol. 2 [AFHRC-K416.01-70]. (SECRET—Information extraction is unclassified.)

17. The remaining material is drawn from the sections on the specific missiles in Ted G. Nicholas, *U.S. Missile Data Book, 1982* (Fountain Valley, Calif.: Data Search Associates, 1981); and *Jane's All the World's Aircraft 1956–57; 1957–58; 1958–59; 1959–60; 1960–61; 1961–62; 1962–63; 1963–64; 1964–65; 1965–66; 1966–67; 1967–68* (New York: Jane's Publishing Co. Ltd.).

18. Chaim Herzog, *The Arab-Israeli Wars: War and Peace in the Middle East* (New York: Random House, 1982), 225.

19. US Army Air Defense School, "Air Defense," vol. 3:48–50; Rosenburg, "National Guided Missile Program," 71, 75, 76, 79, 83, 117–18, 150.

## CHAPTER 3

# VIETNAM

The Vietnam conflict was another war that pitted Western armies and high-technology arms against numerous tenacious foes in primitive terrain. The technology brought with it many advantages, the most significant of which were firepower and mobility. Air power was the most important and visible manifestation of this technology. The guerrillas relied on dispersion, camouflage, mobility, and night operations to neutralize the impact of air power as well as airfield attack and ground-based weapons to directly defend themselves.

## French Operations

Compared to the later American involvement in Indochina, the French conducted smaller military operations with less-modern equipment. The French had but 107 World War II vintage combat aircraft (fighters, fighter-bombers, and bombers) during the decisive 1954 battle of Dien Bien Phu. Here, the French attempted to duplicate their 1953 success at Na San where they used some of their best troops as bait to lure the guerrillas into the open to be cut down by air and artillery fire.

The Vietminh, however, learned the lessons from their previous defeats and increased their antiaircraft protection. The Communist antiaircraft artillery (AAA) forced French aircraft, which had initially flown at 600 to 1,800 feet, to fly at 2,700 to 3,000 feet decreasing French effectiveness. The guns also took a toll on French aircraft. During attacks on the Vietminh supply lines for two weeks after 24 November 1953, 45 of 51 French aircraft were hit by Communist AAA and two were downed. Not surprisingly, flak and air power played a vital role in the actual siege. The Communists opened the battle by attacking French airfields throughout Indochina with artillery and infiltrators and damaged a number of aircraft. A Vietminh artillery bombardment on 10 March initiated the direct attack on Dien Bien Phu and within four days closed the garrison's airstrips. Meanwhile the Communists assaulted the French positions as they fended off French air attacks.

The air portion of the battle saw French aircraft duel Communist flak. Communist antiaircraft guns, 16 Vietminh and 64 Chinese, forced French aircraft higher and higher and disrupted the accuracy of both weapons and supply delivery. Thus, the Vietminh countered French aerial firepower and forced over 50 percent of French airdropped supplies to miss their mark and fall to the Communists. Radar-directed guns hit aircraft flying as high as 10,000 feet. During the battle, the Vietminh downed 48 French aircraft and damaged another 167. More important, they cut off the fortress from the outside and neutralized one of its most potent weapons. Thus AAA played a critical role in the decisive battle of the first Indochina War.[1]

## American Operations through 1968

American involvement in Indochina began in the 1950s, with the dispatch of advisers and equipment. Again the insurgents, this time called Vietcong (VC), lacked air power. The South Vietnamese used American helicopters, which gave them a tactical advantage over the guerrillas (fig. 52). However, the Communists employed discipline and .50-caliber machine guns to counter the choppers, as they demonstrated during the December 1962 battle at Ap Bac. Despite superior numbers and helicopters, the South Vietnamese suffered heavy losses, including five helicopters

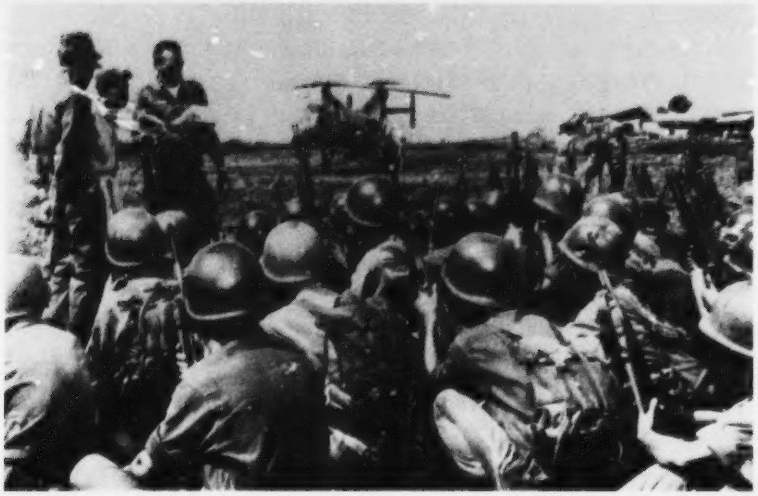


**Figure 52. American adviser instructing South Vietnamese troops on the way to mount and dismount from a CH-21 Shawnee helicopter in 1962.**

destroyed and 14 others hit. The VC continued to exact a steady toll on the aircraft attacking them. On 24 November 1963 in An Xuyen province, for example, Communist ground fire hit 25 aircraft and downed five.[2]

The American presence and air activity steadily increased, and with this increase came losses. The United States suffered its first combat aircraft loss on 2 February 1962, when a C-123 (fig. 53) flying a low-level training mission failed to return. The United States lost 11 aircraft to hostile causes in 1962 and 23 aircraft the next year. The first US Navy loss occurred in Laos in June 1964, one of 60 American aircraft lost in combat in Indochina in 1964.

The air war expanded in May 1964 as the United States began a continuing program of Air Force and Navy reconnaissance flights over Laos. Nevertheless, the Gulf of Tonkin incident in August 1964 marked the start of the American air war in Vietnam, as it led to the first air strike against North Vietnam (fig. 54). Two of the 80 attacking

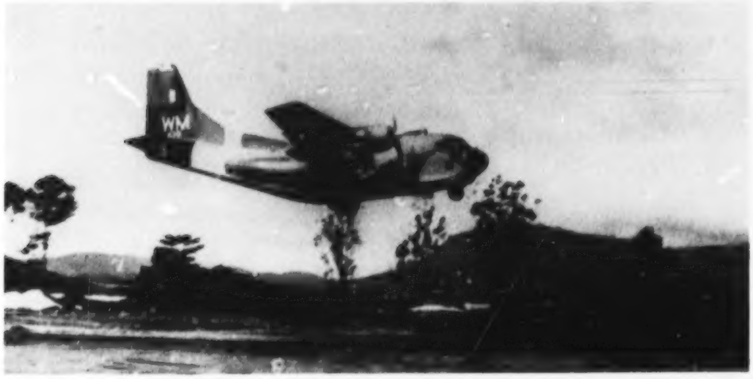


Figure 53. Saigon. An Air Force C-123K Provider, assigned to the 315th Air Commando Wing at Phan Rang Air Base, lifts off from an Army special forces camp airstrip following the delivery of vitally needed supplies.

Figure 54. North Vietnamese scramble for their guns.

Navy planes involved in the reprisal attack went down. Considering the meagerness of the North Vietnamese defenses in terms of quantity and quality at this point, these losses should have been a warning signal to the decisionmakers of what was to come. The air war escalated further with armed reconnaissance and fixed-target strikes in Laos in December 1964. In February 1965 American reprisal strikes on North Vietnam resumed on a "tit-for-tat" basis.

The full-scale bombing offensive against North Vietnam, code-named Rolling Thunder, began in March 1965.[3] On the first mission, 2 March 1965, North Vietnamese gunners downed four of the 130 attacking US and South Vietnamese aircraft. Although the North Vietnamese lacked the most modern equipment, they had no surface-to-air missiles (SAMs) and few jets; they did have numerous conventional antiaircraft artillery weapons. So, while they could not stop the air attacks, they did make them costly.

From the start America used air power against the North as a political tool: first during the reprisal raids and then during the Rolling Thunder campaign. The objectives of the latter were to stiffen the morale of the South Vietnamese, interdict Communist supplies, inflict punishment and cost on the North Vietnamese, and demonstrate American will.[4]

But many, then and now, adamantly proclaim the operation was restricted, some say decisively, by the civilian decisionmakers. Sortie levels were controlled, areas of North Vietnam were put off-limits to air attack, bombing halts were frequent, and targets were carefully selected from Washington; for example, MiG fields were off-limits until 1967, as were missile sites until they downed an American aircraft. In addition, the campaign was graduated, robbing the airmen of the elements of shock and surprise, permitting the North Vietnamese to build and adjust their defenses.[5]

The airmen were also hindered by other factors, the most significant was their unpreparedness to fight a sustained, conventional air campaign.[6] American aircraft were unsuited for these operations. Ironically, "strategic" bombers were used against "tactical" targets in the South, while "tactical" fighters were used against "strategic" targets in the North. The lack of all-weather aircraft presented a considerable burden in the air war against North Vietnam, especially in the winter monsoon season (December through mid-May). The only American all-weather aircraft were the Marine/Navy A-6 (fig. 55) and Air Force F-111, the former entering action in 1965, the latter in 1968. America fought a conventional air war with tactics and aircraft designed for nuclear warfare. The best example of this mismatch was the F-105 (fig. 56). A fighter with an internal bomb bay, a contradiction in terms, it was the US Air Force's workhorse, flying many of the missions over the North and receiving the most damage.[7]

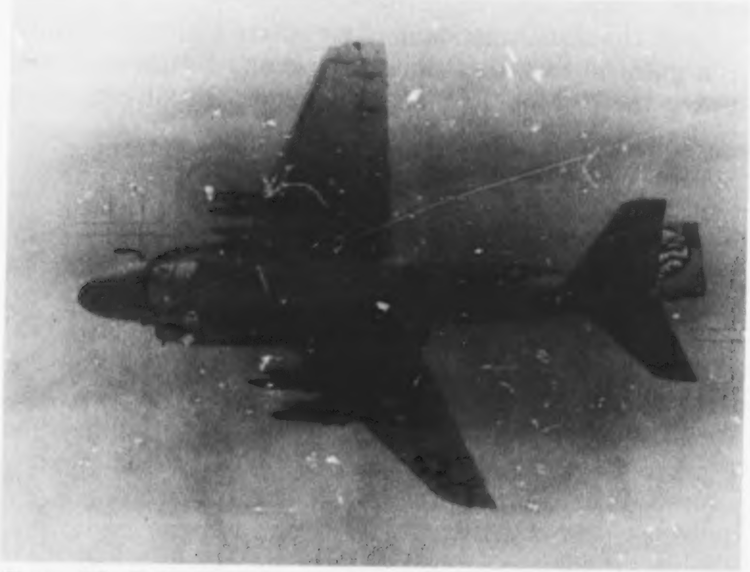


**Figure 55. Gulf of Tonkin. A heavy armed A-6A Intruder attack aircraft heads for a target over North Vietnam while operating off the nuclear-powered attack aircraft carrier USS *Enterprise*.**

**Figure 56. With heavy bombs hanging beneath their aircraft, F-105 Thunderchief pilots head toward a target in North Vietnam.**

The United States, for all of its technological prowess, was ill-equipped in other areas as well. At the beginning of the air war, the United States was still using unguided (dumb) munitions, just as airmen had used in World War I! Thus, aircrews had to overfly their targets, which proved dangerous and often fatal.[8] Second, the United States had neither sufficient nor adequate electronic countermeasures (ECM). Although Strategic Air Command (SAC) B-52s were reasonably equipped, Tactical Air Command (TAC) fighters were not. The irony therefore is that, until late in the war, the better-equipped B-52s operated unopposed over South Vietnam while throughout the war, fighters flew against the growing and much tougher defenses in North Vietnam.

Another factor, perhaps the most important, was that the Americans underestimated the power of the defense and the abilities of the North Vietnamese. The airmen focused on the weapons on which airmen always focus, where the glamour and glory is, fighters and air-to-air combat. It is true that the North Vietnamese built up their air force. But this air force proved as elusive as the Vietcong, using guerrilla tactics of hit and run, and fighting only when circumstances were favorable. With the major exception of operation Bolo in January 1967, when US fighter pilots ambushed the MiGs and destroyed seven without a loss,[9] American airmen did not engage in major air battles and thus were unable to rack up scores as they had in World War II and Korea.[10] Air-to-air combat was neither frequent nor important in the Vietnam air war.

The principal Communist weapon against US aircraft was AAA. American airmen not only underestimated North Vietnamese defenses, they especially underestimated the impact of flak. Both were serious mistakes.

The North Vietnamese fielded a formidable ground-based air defense system. In early 1965 the North Vietnamese manned about 1,200 antiaircraft guns, which they increased to almost 2,000 guns within six months. These guns accounted for about 80 percent of 169 American fixed-wing aircraft lost in 1965.[11] Between 1965 and 1973 flak engaged one-fourth of all flights over North Vietnam and accounted for 66 percent of US aircraft losses over the North.[12]

The farther north the airmen operated, the more intense were the defenses. Although only 20 percent of US sorties over Indochina in 1965 were against North Vietnam, 62 percent of its combat losses were there. The following year, 1966, proved only a little better, with about 30 percent of the total Indochina sorties and just under 60 percent of losses occurring over the North. The area north of 20 degrees latitude, especially around the Hanoi-Haiphong area, proved most dangerous. In the period September 1966 through July 1967, the United States flew less than 30 percent of its North Vietnam attack sorties north of 20 degrees, yet lost 63.5 percent of its aircraft there.[13]

The American airmen initially used nuclear warfare tactics that they had practiced in the late 1950s and early 1960s: high-speed, low-altitude approaches and a rapid climb (pop-up) to bombing altitude just before reaching the target. One adjustment to using conventional ordnance was to make multiple passes over the target. But intense ground fire and the resulting losses forced a change. Therefore the airmen raised approach altitudes to 15,000 to 20,000 feet, from which the aircraft dive-bombed their targets, and limited attacks to a single pass.[14]

The air war changed dramatically on 24 July 1965 when a Soviet SA-2 missile downed an Air Force F-4 (fig. 57) and damaged three others. Proving this shootdown was no fluke, two days later an SA-2 destroyed an American drone. US reconnaissance (fig. 58) spotted construction of the first SAM site in early April and watched it and three other sites progress throughout the spring (figs. 59 and 60). But the decisionmakers would not permit the airmen to attack the missile sites, one of the many political restrictions on the air war. Secretary of Defense Robert McNamara argued that if the airmen attacked the SAM sites, they must also attack the MiG fields, which would be a major escalation of the air war. The leaders also feared that such attacks might cause Soviet casualties. Besides, one of McNamara's chief assistants, John T. McNaughton, believed that the SAMs only represented a bluff and would not be used.[15]

The Soviet antiaircraft missile evolved from German

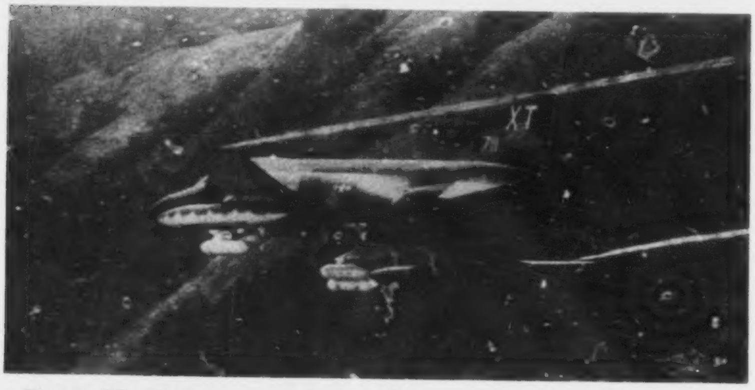


**Figure 57. Phantom attacks. A US Air Force F-4 Phantom dives toward a target in North Vietnam.**

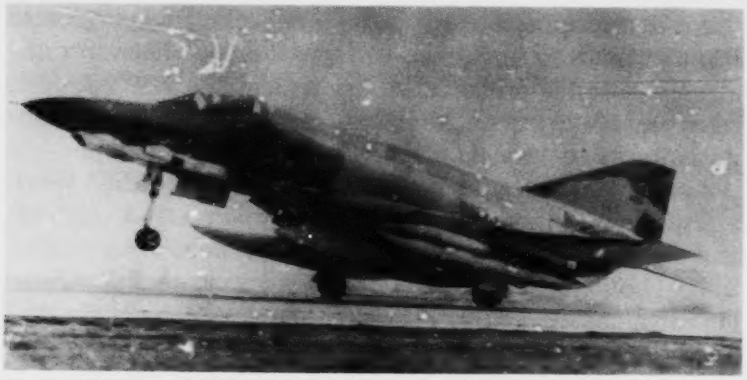


**Figure 58. Reconnaissance version of the high-flying Mach 2-plus fighter-bomber, the RF-4C, is equipped for sophisticated day and night reconnaissance work.**

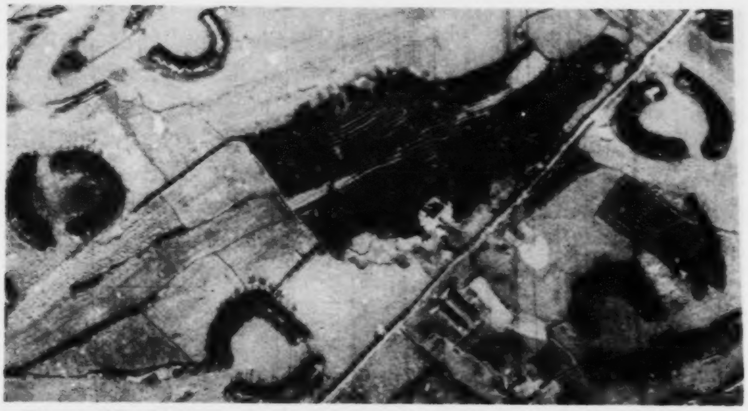


**Figure 59. Surface-to-air missile site in North Vietnam that has been abandoned and returned to cultivation.**

World War II programs. The first Soviet SAM, the SA-1, was a German Wasserfall with ground (command) guidance. It became operational in early 1954. The West first saw its successor, the SA-2, in 1957. The Soviets designed this missile to defend against high-flying, essentially nonmaneuvering, strategic bombers. The SA-2 measured 35

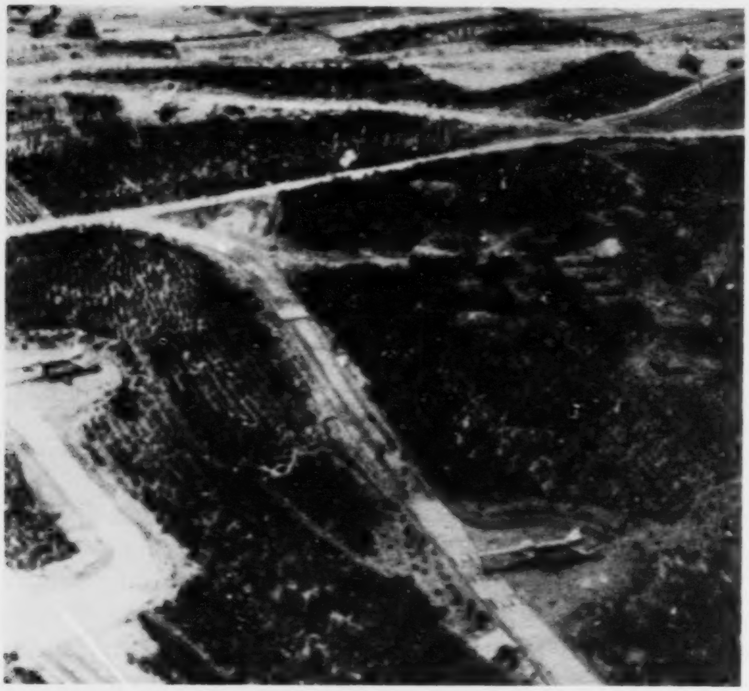
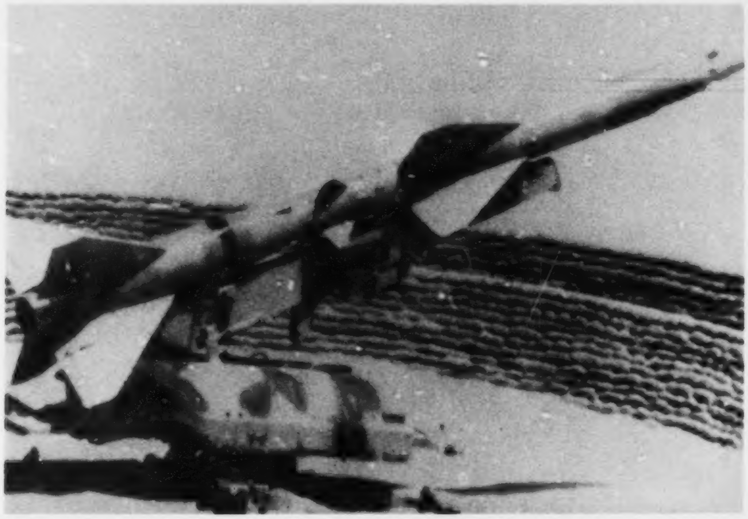


Figure 60. North Vietnamese SA-2 position.

feet in length and weighed 4,875 pounds with its booster. It could carry a 288-pound warhead at Mach 3.5 out to a slant range of 24–25 miles and was effective between 3,000 and 60,000 feet (fig. 61). The SA-2 first achieved prominence by knocking down an American U-2 over the Soviet Union in the spring of 1960 and downing another U-2 over Cuba in October 1962 (fig. 62).[16]

Despite knowledge of the missile since 1957, and its potential (similar to the Nike Ajax), the United States made only mixed progress with countermeasures. Tight budgets in the late 1950s hampered these efforts. Airmen assigned high priority to countermeasures against the SA-2 in budgets for fiscal years 1964 and 1965, but had nothing effective in hand when the need arose. As a result, in 1964, some



*(Photo Credit: US Army Air Defense Artillery Museum)*

Figure 61. Soviet SA-2.

Figure 62. SA-2 launch against US aircraft.

airmen believed that aircraft could not operate in SAM-protected areas. Although it is easy and partially correct to blame the tight funding, it is also true that the airmen underestimated the requirement for countermeasures. Although the US Air Force equipped strategic bombers with warning and jamming devices in the late 1950s, it did not similarly equip tactical fighters and bombers. Whatever the reason—money, obsession with nuclear weapons delivery, electrical power requirements, trust in fighter maneuverability and speed—the tactical air forces were unprepared for combat.[17]

The potential SAM threat grew as the North Vietnamese incorporated more missiles into their inventory. North Vietnamese SAM battalions increased from one in 1965 to 25 the next year, to 30 in 1967, and to 35–40 in 1968. This growth in units permitted the North Vietnamese to increase their missile firings from 30 per month in the first 11 months of operation to 270 per month between July 1966 and October 1967. The latter month, with between 590 and 740 SAMs fired, was the peak month of firing until the Linebacker II operations of 1972. From October 1967 to the bombing halt on 1 April 1968, SAM firings averaged 220 per month. During this period, the American airmen observed 5,366–6,037 SAMs, which downed 115–128 aircraft.[18]

Despite the increase in SAM firings, their direct effectiveness declined. In 1965 it took almost 18 SAMs to down each American aircraft, a figure that rose to 35 in 1966, to 57 in 1967, and to 107 in 1968. A number of factors contributed to this decline.[19]

The airmen quickly learned that the SA-2 could be outmaneuvered. The Soviets designed the SA-2 to destroy high-flying, nonmaneuvering, strategic bombers; but until 1972 it engaged primarily low-flying, very maneuverable, tactical fighters. On clear days, alert airmen could spot SA-2 launches as the missile was large, described by most flyers as a flying telephone pole, and left a visible smoke trail.

The pilots would rapidly dive toward the missile, and when it changed direction to follow the aircraft, the pilot would pull up as abruptly and as sharply as possible. The SA-2 just could not follow such maneuvers. But such action required sufficient warning, proper timing, and, of course, nerve and skill. To give pilots adequate time to maneuver, procedures prohibited the pilots from flying too close to clouds between them and the ground. Later, the airmen received electronic devices that gave a visual and aural warning when a SAM radar was tracking (painting) an aircraft.[20]

The American airmen also directly took on the missiles. On 27 July, 46 US Air Force fighter-bombers attacked two missile sites, met disaster, and according to a CIA report, hit the wrong targets. North Vietnamese gunners downed three aircraft while a midair collision accounted for two others. Nevertheless, the anti-SAM attacks continued. In the first nine months of 1966, the airmen launched 75 strikes against 60 sites and claimed to have destroyed 25 and damaged 25. Such attacks proved unprofitable because of the mobility of the SAMs—they could be relocated within hours.[21]

One effort to counter North Vietnamese SAMs was standoff ECM: aircraft crammed with electronics gear that orbited a distance from the defenses and interfered with Communist radar and SAM signals. The Marines employed EF-10Bs in this role between April 1965 and 1969. The Douglas Skyknight was ancient, having first flown in 1948 and seen action in the Korean War as a night fighter. It was joined in the ECM role in late 1965 by another Douglas product, the Skywarrior, which first flew in 1952. The Navy employed the Skywarrior as an electronics warfare aircraft designated as the EKA-3B. The Air Force adopted the Navy aircraft and also used it in the ECM role as the EB-66C, which carried a crew of seven, including four ECM operators in a crew compartment fitted in the bomb bay. Joined by other ECM versions of the B-66, it served throughout the war. However, the North Vietnamese moved their SAMs, forcing the EB-66 in turn to move away from North Vietnam to orbits over both Laos and the Gulf of Tonkin. In January 1968 a Vietnamese MiG downed an EB-66C (fig. 63).[22] In late 1966 the Marines introduced the EA-6A in the jamming role.

A third American measure against the SAMs was code-named Wild Weasel. The Air Force installed radar homing and warning (RHAW), electronics equipment that could detect SAM radar and indicate its location, into F-100Fs, the two-seat trainer version of its fighter-bomber. Wild Weasel I went into action in November 1965, flying with and guiding conventionally armed F-105s against SAM positions. These operations, known as Iron Hand (SAM suppression), preceded the main force by about five minutes, attacked and harassed the SAMs and thus permitted operations at 4,000–6,000 feet above the light flak into which the SAMs had forced the American aircraft.[23]

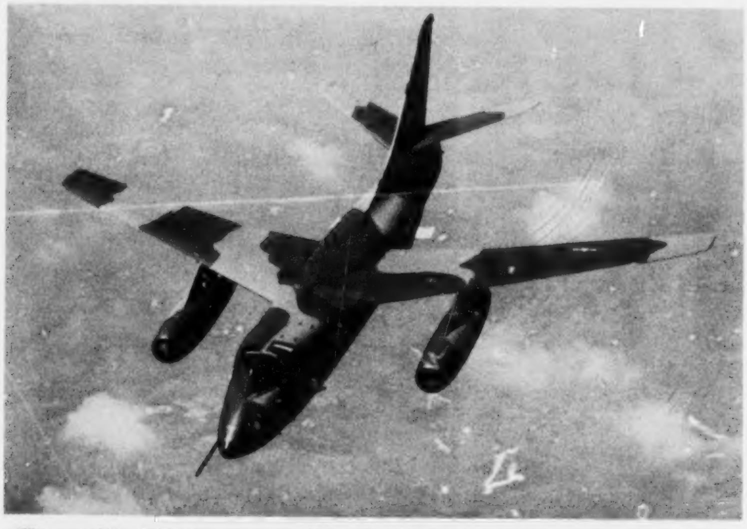


**Figure 63.** **US airmen employed standoff jammers. US Air Force EB-66, of the 355th Tactical Fighter Wing, in flight.**

In April and May of 1966 the American airmen first used the Navy's AGM-45A Shrike missiles (fig. 64). Now the anti-SAM crews had a standoff weapon that homed in on the SAM's radar signal. However, the Shrike had limited range and maneuverability and could be confused. These liabilities reduced the antiradiation missile's (ARM) effectiveness as did Communist countermeasures. The North Vietnamese crews soon learned that by limiting emissions and coordinating several radars, they could still operate the SAMs and yet limit their vulnerability to the Wild Weasels. Just as the North Vietnamese used decoys to neutralize and ambush American air strikes, SAM operators sometimes turned on their radar to provoke an ARM launch and then turned it off before missile impact. The Shrike's kill rate declined from 28 percent of those launched by Air Force and Navy crews in 1966 to 18 percent in the first quarter of 1967. In the fall of 1967 SA-2 crews began using optical aiming, which rendered American ECM efforts useless; however, optical aiming required visual conditions, which also reduced SAM effectiveness. In March 1968 the Americans introduced the longer-range and more capable AGM-78 Standard ARM. Although it was constrained by reli-

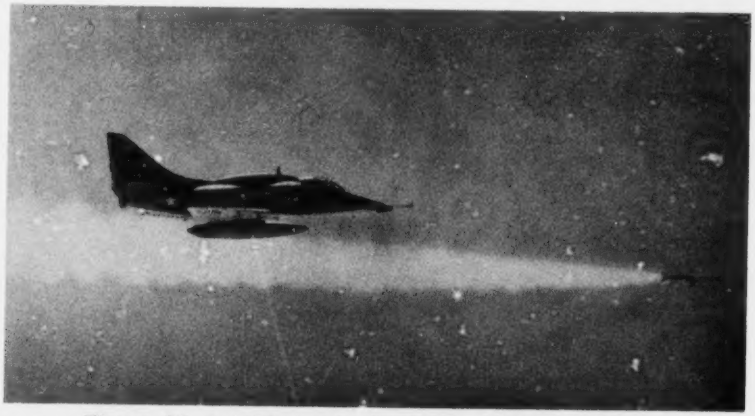


**Figure 64. A-4 Skyhawk aircraft fires Shrike missile.**

ability and size problems, nevertheless, the AGM-78 gave American airmen another weapon against the SAM.[24]

In the summer of 1966 Wild Weasel III appeared in the form of the two-seat F-105 trainer, redesignated F-105G (fig. 65). Iron Hand operations were now easier as compatible aircraft were flying together. In late 1966 US airmen began using cluster bomb units (CBU—antipersonnel munitions) against North Vietnamese positions. But in the period following the 1968 bombing halt, 1969 until summer 1972, free-fall munitions were removed from Iron Hand aircraft, degrading their effectiveness. By then, however, the airmen had another weapon with which to combat the SAMs.[25]

The Navy in mid-1966 and the US Air Force in October tested ECM pods carried beneath the fighters. A formation of fighters using the pods, the Navy's ALQ-51 and the Air Force's QRC-160—redesignated ALQ-71—seriously inhibited radar-directed defenses. The pods permitted opera-

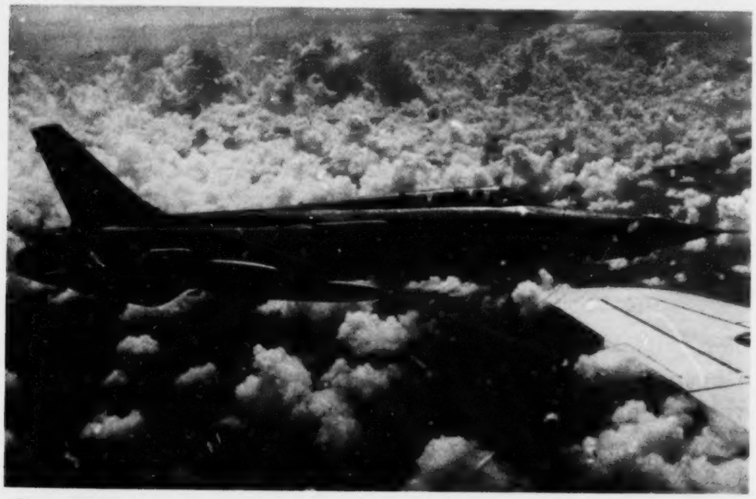


**Figure 65. Wild Weasel. US Air Force F-105G on the wing of a tanker during the Strategic Air Command's Linebacker refueling operations. The aircraft is armed with two Shrike missiles.**

tions between 10,000–17,000 feet, above the reach of light and medium flak. Put into service in January 1967, the pods further neutralized Communist defenses. But unfortunately for the airmen, the formation required for the best ECM results made the aircraft vulnerable to MiG attack. The various jamming devices forced the SAM operators to adopt a new procedure, track-on jamming. They fired the SA-2s at the jamming signal, but as it gave azimuth and not range information, it proved much less accurate than the normal method.[26]

## American Operations through Linebacker I

The 1968 Tet offensive changed the war for the United States. As a result, President Lyndon B. Johnson capped American troop levels, stopped American bombing of the North above 20 degrees north latitude, and then, just before the November election, stopped all bombing of the North. Americans elected Richard M. Nixon president, who began to withdraw US troops and turn the burden of the war over to the South Vietnamese. As a result, American aircraft losses, especially fixed-wing machines, declined.[27]

The air war raged in other areas besides North Vietnam; however, losses in the North were proportionally the greatest. American combat losses on a per sortie basis were next highest over Laos, then South Vietnam, and lowest over Cambodia. But because American airmen flew most of their sorties over the South, this is where most of the aircraft fell. Between 1961 and 1968, 859 aircraft were lost to hostile action over the North compared with about 1,709 over the South. One sharp difference was the proportion of helicopters destroyed in the two areas. Only 11 went down in North Vietnam, but about 1,073 helicopters (or about 63 percent of all aircraft lost in the South) were lost in South Vietnam.[28]

The helicopter proved to be vulnerable even in the less-lethal antiaircraft environment of South Vietnam where most American rotary-wing aircraft operated (fig. 66). The vulnerability of the chopper is highlighted by the deaths associated with it. During the course of most of the war (1961–71) in all of Southeast Asia, about 62 percent of the deaths from combat aircraft losses and 66 percent of noncombat aircraft losses were attributed to helicopters. These numbers may overemphasize the point because helicopters were employed in large numbers, as troop carriers, near the ground, and where ground fire was intense, all of which led to high personnel losses (figs. 67 and 68). Helicopter vulnerability was dramatically demonstrated in the 1971 South Vietnamese invasion of Laos (Lam Son 719). Although official figures put losses at 107–122 and the number of helicopters damaged at 600, some put these figures much

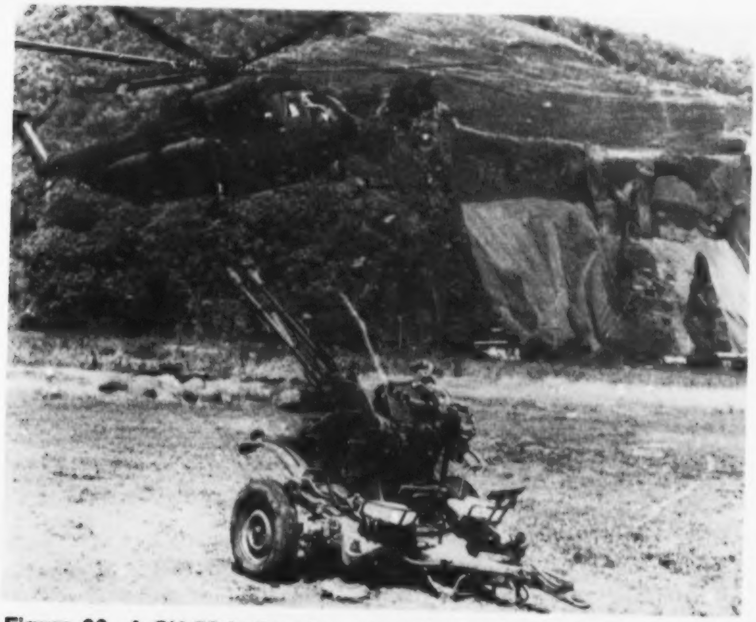


**Figure 66. A CH-53 helicopter moves in to take a closer look at a captured Soviet twin-barrel antiaircraft gun.**

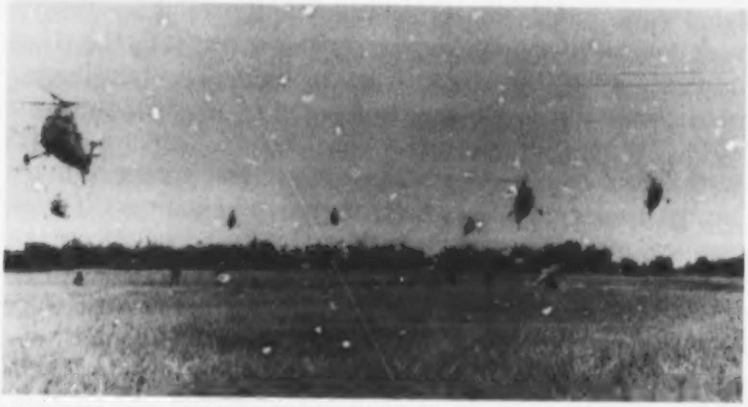


**Figure 67.** One characteristic of the Vietnam War was the extensive Allied use of the helicopter. Here VNAF Choctaws "fan out" as they enter the landing zone.

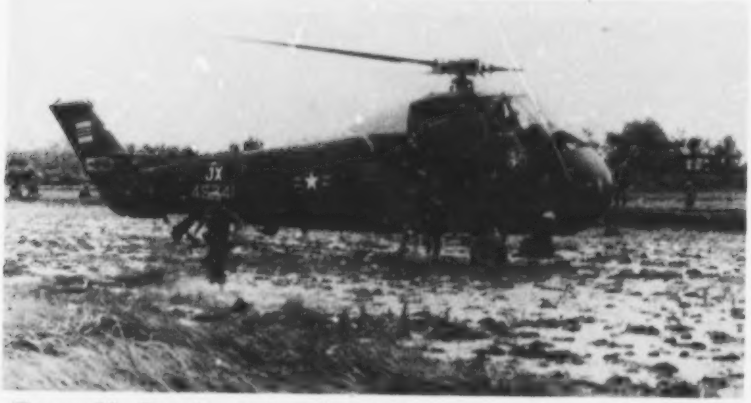


**Figure 68.** Popular and regional forces scramble out of an H-34 through the paddies of the delta.

higher, as high as one-third lost of those engaged. The same doubts cloud the official Army figures which acknowledge 2,166 helicopters lost in combat and 2,075 lost to noncombat causes during the entire war. There are allegations that the Army disguised the magnitude of their chopper losses by repairing many damaged machines that did not deserve such efforts. One source states that the Communists downed 5,600 Army helicopters, but the Army successfully retrieved two-thirds of these. One critic puts total helicopter losses at 10,000.[29]

In March 1972 the North Vietnamese attempted to knock the South Vietnamese out of the war with a massive conventional invasion. The Communists used weapons heretofore not seen in the war in the South: tanks, 130-mm artillery, and the SA-7 (fig. 69). The latter is a shoulder-launched, man-portable, heat-seeking missile with a range of just under two miles and able to reach almost 10,000

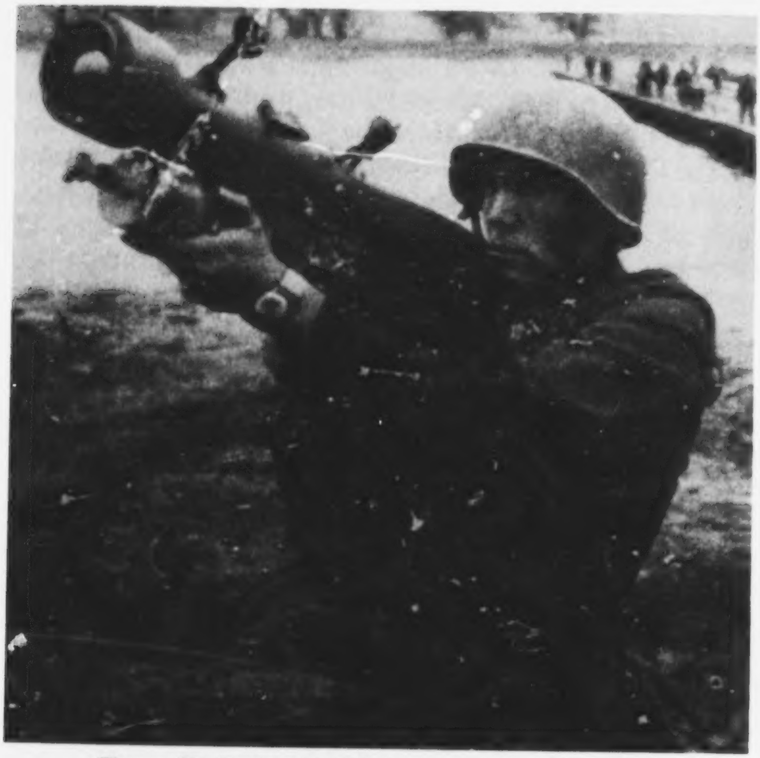


**Figure 69. Soviet SA-7 Grail surface-to-air missile.**

feet. The SA-7 gave the guerrillas a potent weapon against air power and put the slow-moving, low-flying aircraft, especially helicopters and propeller aircraft, at considerable risk. It knocked down a number of helicopters and observer aircraft and in June a AC-130. Between 29 April and 1 September, the Communists fired 351 SA-7s at American aircraft in 221 incidents and downed 17 fixed-wing and nine rotary-wing aircraft. Aircraft flying low and slow proved especially vulnerable to the SA-7s. It took 1.8 missiles to down each helicopter compared to 10 required for each slow-moving fixed-wing aircraft kill (all propeller aircraft except for one A-37), and 135 missiles to destroy one F-4. The American airmen used flares to decoy the SA-7, but most effective of all, they increased both their speed and altitude. Thus, although the number of aircraft downed was not great, the SA-7's major impact was to force American aircraft to fly higher where they were less effective and to put some aircraft, such as the A-1, out of business.[30]

The Communists employed their SA-2s differently during the 1972 campaign. They preceded their invasion by deploying SA-2s to cover the demilitarized zone, and on 17 February 1972, fired 81 missiles which downed three F-4s. In March SA-2s downed two AC-130s over Laos and the next month an EB-66. The SA-2s also took on the B-52s which now ventured further north. The Communists fired 23 SAMs on both 21 and 23 April in defense of Vinh and destroyed a B-52, the first Boeing bomber lost to Communist fire. During Linebacker (later called Linebacker I), the code name for the renewed air attacks of the North in 1972, the Communists fired 2,750 SA-2s at US aircraft and downed 46 planes.[31]

Just as North Vietnam changed the rules of the game, so did the United States. Nixon's policy of détente gave him flexibility that his predecessor—who feared direct intervention by the Soviets, or more likely, the Chinese—lacked.[32] The president authorized the mining of North Vietnamese ports, long requested by the military, and used air power as it had not been used before. The airmen used air power more effectively because they had fewer political restrictions, although some targets and areas continued to be denied to them.[33]

Thus, US air power played a major role in stopping the invasion by inflicting terrible losses on the North Vietnamese forces. As never before, American airmen had targets they could see, hit, and destroy. The airmen also had better weapons.

Although the airmen introduced no new aircraft since the 1968 bombing of North Vietnam, they did use other equipment that improved bombing effectiveness. These devices put more bombs on target, thus reducing the exposure of friendly aircraft to hostile fire. The airmen began long-range aid to navigation (LORAN) bombing in 1970, which made it possible to operate in the worst weather conditions and still get bombs within hundreds of meters of the aiming point.[34] Although this was not precision bombing, it did permit bombing during bad weather.

The most spectacular new equipment introduced were guided munitions (smart bombs), which could get bombs within meters of the target. A number of bridges that had withstood numerous, costly American strikes quickly fell to these new weapons. For example, on 13 May 1972 four flights of F-4s attacked the formidable Thanh Hoa Bridge with guided bombs, dropping its western span and causing other critical damage. There were no US losses in the attack, whereas the previous 871 sorties had cost 11 aircraft and had not neutralized the bridge. The airmen considered the guided bombs to be 100 times as effective as unguided weapons against bridges and 100–200 times as effective against hard targets such as bunkers.[35]

The Americans employed new ECM and anti-SAM tactics to combat the formidable Communist defenses. Against North Vietnamese electronics, they employed more chaff, a World War II device that still worked. Chaff had been seldom used because the Navy feared its impact on their shipborne radar and the US Air Force lacked a suitable dispenser. In June 1972 American airmen introduced the ALE-38 chaff dispenser (fig. 70), and in August chaff bombs. Both devices greatly enhanced US ECM capabilities and reduced the vulnerability of chaff dispensing aircraft. The US Marines introduced a new jamming aircraft, the EA-6B (fig. 71), into action in July 1972.[36]

The Americans also changed their anti-SAM tactics (Wild Weasel) from Iron Hand, four F-105s using antiradiation missiles. In August the US Air Force formed hunter-killer teams consisting of two F-105 hunters armed with ARMs and two F-4 killers armed with CBUs.[37]

If the airmen operated successfully over North Vietnam, they nevertheless paid a price. During the April through October 1972 bombing, the US Air Force flew 9,315 sorties and dropped 155,500 tons of bombs on the North and lost 63 planes. In all, the United States lost 111 fixed-wing aircraft in combat, apparently in equal proportion to AAAs, MiGs, and SAMs. In addition to aircraft losses, the airmen

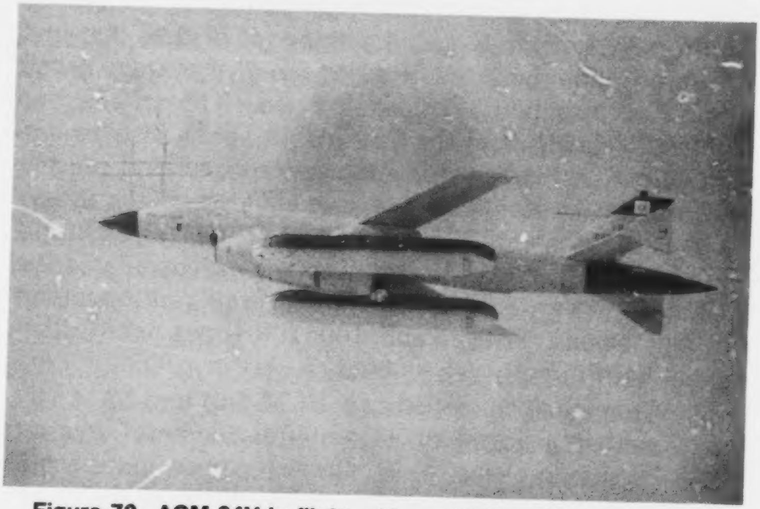


Figure 70. AQM-34V in flight with an AN/ALE-38 chaff pod on each wing.

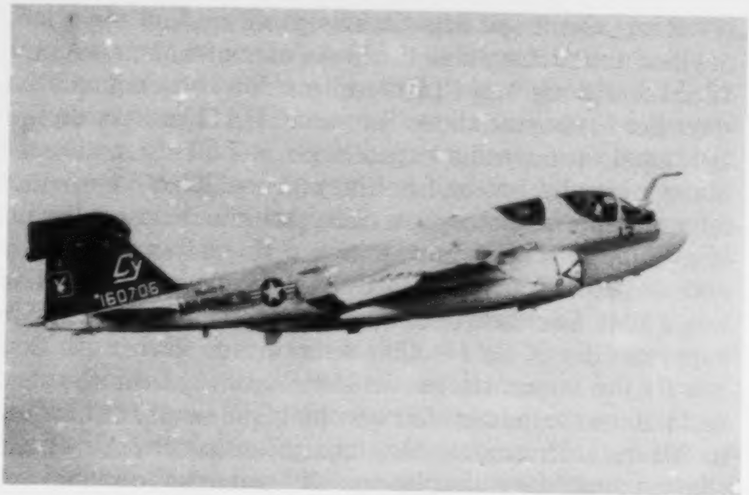


Figure 71. Marine EA-6B Prowler aircraft.

paid another price: only 2,346 of the total sorties were directly attacking enemy installations; the others were in support. In fact, the ratio of support aircraft was even higher than these numbers indicate (3.4:1), as they do not include tanker and reconnaissance aircraft.[38]

As the bombing took its toll in the North and the invasion of the South stalled and then was pushed back, negotiations prompted Kissinger's "peace-at-hand" comment on 26 October. But, as close as the peacemakers got to an agreement, they did not get a treaty.

## Linebacker II

On 14 December President Nixon gave the North Vietnamese 72 hours to get back to serious negotiations "or else." The "or else" was a three-day bombing offensive against North Vietnam, which Nixon ordered that day and then changed on 19 December to an indefinite period. The object of Linebacker II, the code name for the December bombing, was to get negotiations going again.[39]

US airmen returned to the home of the SAMs, AAA, and MiGs on the night of 18 December.[40] For three consecutive days the script was about the same. F-111 attacks on airfields and various other targets began at 7:00 P.M. and lasted about nine and one-half hours.[41] About 20 to 65 minutes later, the first of three waves of B-52s unloaded their bombs (fig. 72). The second wave followed about four hours later and was, in turn, followed by the third wave about five hours later. Each wave consisted of between 21 to 51 B-52s supported by 31 to 41 other aircraft, and each wave flew exactly the same pattern: the same heading from the west and, after a sharp turn after bombing, the same exit heading to the west. There were also daylight attacks by Air Force, Marine, and Navy aircraft.

The bombing rocked Hanoi, but the aircraft losses rocked the airmen as well. During the first three days of the operations, 12 aircraft went down, not a large number and seemingly bearable; however, the B-52 losses, three on the

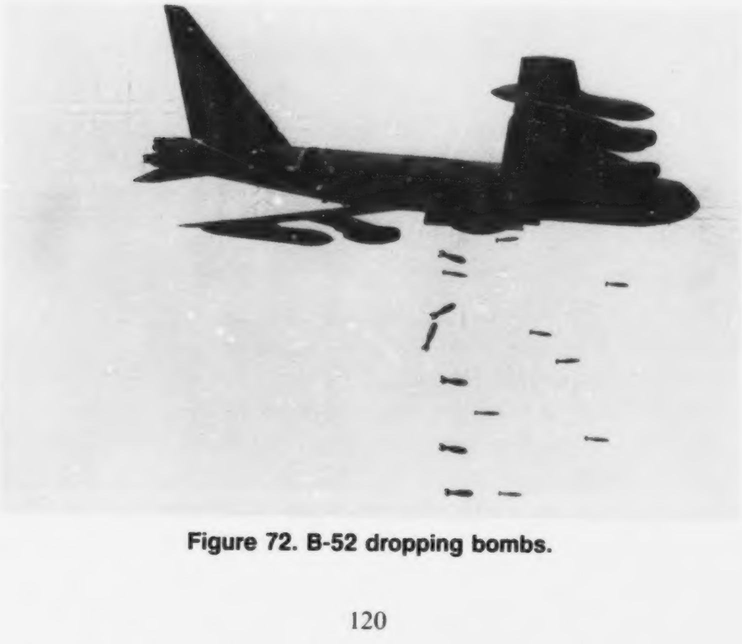


**Figure 72. B-52 dropping bombs.**

first night and six on the third, were shocking. The B-52s were, after all, America's primary strategic nuclear bomber, the foundation of the air-breathing leg of the Triad. Up to this point, the US Air Force had lost only one B-52 to enemy fire, although 17 had been lost to other causes. Although the overall B-52 loss rate of 3 percent of effective sorties on the three missions appears acceptable, the loss rate on the third mission was 6.8 percent, and the nine B-52s represented almost 5 percent of the 170 to 210 B-52s the US Air Force had deployed in Southeast Asia and over 2 percent of the 402 in service in 1972.[42] This is reminiscent of the summer and fall of 1943 over Germany.

The B-52 losses highlighted a number of problems. First, the B-52 fleet was of mixed quality, consisting of 107 of the older but modified "D" models and 99 of the later "G" models. Only half of the "G" models had upgraded ECM equipment, which proved to be one of the critical factors in determining which aircraft were hit by the SAMs, the big killers of the B-52s (fig. 73).[43] Even though the defenders fired more SAMs at the B-52Ds, the B-52Gs were hit and

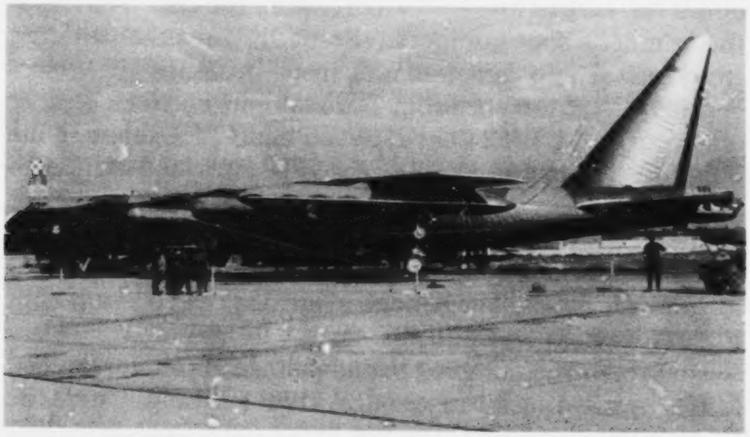


**Figure 73. B-52 aircraft that made an emergency landing at Da Nang, AB, South Vietnam, after being damaged by a SAM missile.**

downed more often, five destroyed on the first three missions.

A second problem was that the B-52s were controlled, or better put, overcontrolled, from SAC headquarters in Omaha. SAC formed the basic battle plan and tactics literally thousands of miles from the actual combat. Initially, SAC had a policy of no maneuvers on the bomb run, although such maneuvers often permitted aircraft to elude the SAMs.[44] SAC also mandated a "press-on" procedure which dictated that bombers continue their missions despite the loss of engines, computers, and most critically, ECM equipment.[45] Not surprisingly, with one headquarters controlling the bombers and another the support aircraft, there was a lack of coordination between the bombers and their escorts, including two instances in which B-52s fired on US aircraft.[46] Other coordination problems included US radios jammed by EB-66 ECM and friendly radar severely degraded by B-52 ECM.[47]

Losses indicated that the ECM, the key to fending off the SAMs, was inadequate. First, B-52 ECM protection markedly declined in the 100-degree turn immediately after bomb release because the bank reduced the effectiveness of the bomber's spot jammers.[48] Second, winds that differed from forecasts in direction and speed upset the ECM protection of the chaff corridors. For example, on 20 December only four of 27 B-52 cells received chaff protection at the bomb-release line, and all of the B-52s downed were 5 to 10 miles from chaff cover.[49] Third, the North Vietnamese gunners surprised the American airmen by using a radar designed and deployed for gun control (designated T8209) to guide the SA-2s. The American airmen lacked equipment to both warn of and jam this "new" I-band radar.[50]

The North Vietnamese took advantage of the stereotyped tactics by salvoing barrages of SAMs at the point where the B-52s executed their posttarget turns. The SAM operators limited radar guidance to the last five to 10 seconds of intercept, which made the tasks of the ECM operators and

Wild Weasels very difficult.[51] The American losses indicated that the airmen had to modify their operations.

Thus the Air Force formed a tactics panel and changed tactics.[52] Although most US aircraft continued to fly their missions about the same way, this was not true for the B-52s. On the four missions between 21 and 24 December, only 30 B-52Ds were employed in a single wave. In addition, the planners varied the timing, headings, and altitudes. The airmen increased the amount of chaff, attempting to lay a chaff blanket instead of a chaff corridor. Thus, instead of 15 percent of the bombers receiving chaff protection at the bomb release point, now 85 percent did. In all, US airmen dropped 125 tons of chaff during Linebacker II. Night hunter-killer teams were first used on 23 December to nullify the SAM threat; however, bad weather permitted only marginal results. The Air Force also quickly installed jammers and modified ARMs for use against the I-band radar that had surprised them.[53] But the American airmen initially lacked the AGM-45 A-6 suitable for this job and did not get these missiles until 27 December. The AGM-78 (fig. 74) which also could be used against this band of radar, was in short supply even before the commencement of Linebacker II.[54]

The airmen hit Hanoi with these new tactics on 21 December and lost two B-52s and one A-6A. During the next three nights bombs fell on targets in Haiphong and north of Hanoi. The new tactics and new targets paid off as the airmen lost only three aircraft on these three missions. There was no bombing on 25 December, perhaps a gallant, certainly a diplomatic gesture that allowed North Vietnamese defenders to rearm.

The attack on 26 December was one of a kind. The United States sent 120 B-52s, the most on any of the Linebacker missions, against targets in Hanoi and Haiphong. Although supported by 99 aircraft, two B-52s went down. Both followed SAC's "press-on" procedures, attacked in broken cells—formations of two rather than the normal

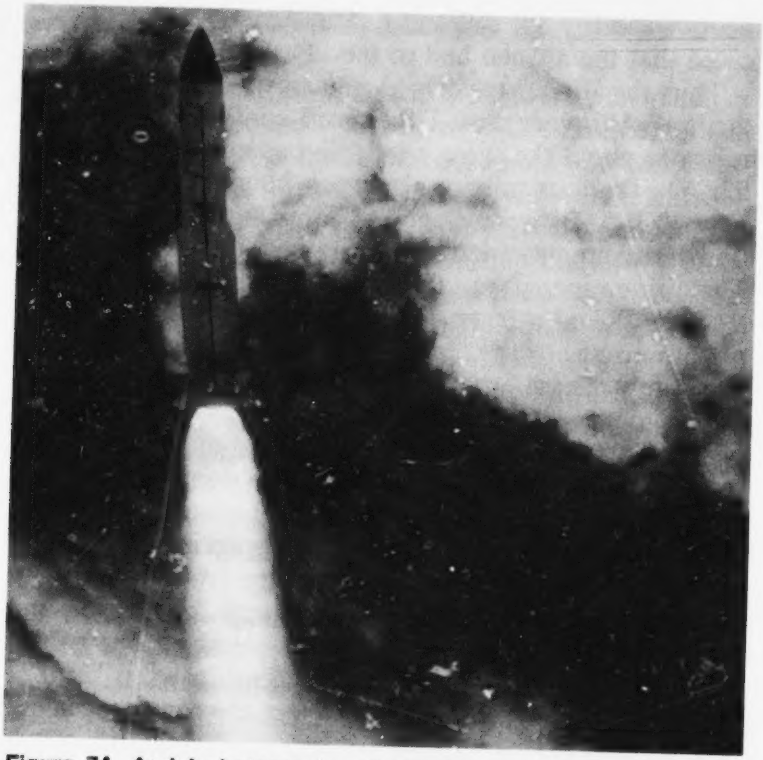


**Figure 74. Aerial photography of standard arm missile (AGM-78) igniting, Haiphong, North Vietnam, 19 August 1972.**

three bombers—and thus lacked adequate ECM power.

The remaining three missions (27–29 December) employed 60 B-52s each night, but otherwise fit the same pattern. Five aircraft (two B-52s) went down on 27 December. There were no losses on the last two days.

In all, the B-52s dropped about 15,000 tons of bombs, while tactical aircraft added another 5,000 tons of bombs.[55] Because there were only 12 hours of visual conditions during the 12-day operation, the airmen aimed the bulk of their ordnance by nonvisual techniques such as radar and LORAN.[56]

Despite North Vietnamese claims of 81 aircraft destroyed

(38 B-52s), Linebacker II cost 27 aircraft of which 15 were B-52s.[57] Compared to the 3 percent expected losses,[58] the overall loss rate of below 2 percent and a B-52 loss rate slightly above 2 percent were acceptable. Thus, airmen favorably compared the loss rates in Vietnam and especially those of Linebacker II with those in World War II and Korea. Such a comparison, however, disregards the fact that Vietnam-era aircraft were much more expensive than their predecessors, at the same time inventories and aircraft production were much smaller.[59]

The American airmen throttled two parts of the North Vietnamese air defenses. The small Communist air force launched 32 aircraft, attempted interceptions with 20, but scored no hits on the B-52s, and downed only two F-4s for the loss of six MiGs.[60] American tactics (ECM, night, and high-altitude operations), bad weather, and fighter escorts nullified the MiGs. All but the latter did the same to North Vietnamese AAA, which damaged only one B-52 and downed three tactical aircraft.[61] But if the American airmen adequately handled the fighter and flak threats, the same cannot be said of the SAMs.

During Linebacker II, the North Vietnamese fired 1,285 SAMs which downed all 15 B-52s lost, as well as three other aircraft.[62] The American airmen, however, did not target the SAM sites until the sixth mission on 23 December and did not attack them again until 27 December when B-52s and F-111s attacked the most effective single SAM site, credited with downing five to nine B-52s.[63] US Air Force hunter-killer units also attacked this site, designated by the Americans as VN 549, with at least nine AGM-45s and two AGM-78s. But VN 549 survived, and therefore, on 27 December briefers instructed the American bomber crews to fly well clear of it. Rumors, never confirmed, circulated that it was manned by Chinese gunners. The B-52 and F-111 attacks on SAM sites continued on the last two days of the operation, along with F-4 attacks on SAM storage facilities. Despite these efforts, intelligence estimated that only two sites were 50 percent damaged, eight were undamaged, and results against three were unknown.[64] It should be noted that only 3 percent of the bombs fell on SAM targets as compared with 5.3 percent that fell on airfields.[65] The saving grace was that by 29 December the North Vietnamese had run out of SAMs, leaving the North essentially defenseless.[66]

Clearly Linebacker II was an outstanding feat of arms. After years of restrictions and frustrations, American airmen were able, in typical blunt American fashion, to directly take on and defeat a formidable air defense system. For the United States, and especially the airmen, this was a proud, satisfactory way to *end* the war, or at least end American involvement. But the tactical aspects, the *victory*, should not obscure the fact that strategic bombing did not achieve decisive ends in Vietnam: the final treaty was substantially the same as the agreements made in October.[67]

## Conclusions

The American airmen were unprepared for the war fought in the skies over Southeast Asia: unprepared in terms of the political restrictions levied on them, the scant targets they had to attack, and the nature of a long conventional war they had to fight. As the realities of battle forced them to change both their tactics and equipment, the airmen had to relearn the lessons of the past, and in the process suffered substantial losses. They again found that enemy antiaircraft defenses, SAMs (but most of all AAA) rather than aircraft, presented the major obstacle to air operations. They again learned how dangerous it was to fly close to the ground in the face of intense ground fire. They again realized that attacking enemy antiaircraft positions (SAM and AAA) was dangerous and of dubious value. Most of all, they saw that the tactics used in World War II and Korea were relevant for modern air warfare.

SAMs greatly enhanced the power of the defense and represented new difficulties to the airmen. Their impact must be measured not only by the number of aircraft they destroyed, but in two other ways. First, SAMs forced aircraft into the teeth of the guns, which were very effective. Second, to counter the missiles, the airmen had to expand the total number of support sorties, a requirement which increased as the war progressed. Another disturbing weapon introduced was the man-portable SAM. Although not possessing great lethality, it was easily concealed, highly mobile, and it gave one man the power to down a multimillion dollar aircraft.

Countermeasures helped keep American aircraft losses to a manageable rate. One Air Force officer estimated that ECM reduced losses by 25 percent, while a Navy officer put the figure at 80 percent.[68] Nevertheless, air operations were expensive both in losses and effort. Communist gunners proved a worthy and resourceful foe, although limited by second-rate Soviet equipment. Yet, despite the able Communist air defense tactics and their adaptation to the changing tactical situation, the American airmen gradually increased their edge. The big improvement for the offensive side came with the use of ECM and antiradiation and standoff weapons. These increased accuracy and decreased losses. In the full-scale operations of Linebacker II, the American airmen showed that massive application of modern aircraft with modern equipment could succeed against defenses limited in numbers and quality.[69]

## NOTES

1. Bernard Fall, *Hell in a Very Small Place: The Siege of Dien Bien Phu* (Philadelphia, Pa.: J. P. Lippincott, 1966), 31–34, 49, 133, 144, 454–55; William Leary, "CAT at Dien Bien Phu," *Aerospace Historian*, September 1984, 178–80, 183; Robert F. Futrell, *The United*

*States Air Force in Southeast Asia: The Advisory Years to 1965* (Washington, D.C.: Office of Air Force History, 1981), 19–20, 116; V. J. Croizat, trans., *A Translation from the French: Lessons of the War in Indochina*, vol. 2, Rand Report RM-5271-PR (Santa Monica, Calif.: Rand Corp., May 1967), 292, 302.

2. Futrell, *The United States Air Force in Southeast Asia*, 158–59, 163, 196.

3. Benjamin F. Schemmer, "Vietnam Casualty Rates Dropped 37% after Cambodia Raid," *Armed Forces Journal*, 18 January 1971, 30; Michael McCrea, "U.S. Navy, Marine Corps, and Air Force Fixed-Wing Aircraft Losses and Damage in Southeast Asia (1962–1973)," Center for Naval Analyses study, August 1976, 2-1, 2-13, 2-19, 2-20 [AUL-M31914-22]; Futrell, *The United States Air Force in Southeast Asia*, 116.

4. *The Pentagon Papers*, ed. The Senator Gravel (Boston, Mass.: Beacon Press, 1975), 3:269; Lon O. Nordeen, *Air Warfare in the Missile Age* (Washington, D.C.: Smithsonian Institution Press, 1985), 11.

5. *The Pentagon Papers*, 3:294–95; Nordeen, *Air Warfare in the Missile Age*, 15, 18; U. S. Grant Sharp, *Strategy for Defeat: Vietnam in Retrospect* (San Rafael, Calif.: Presidio Press, 1978), xiii-xiv, 271; Lou Drendel, *. . . And Kill MiGs: Air to Air Combat in the Vietnam War* (Carrollton, Tex.: Squadron Signal Publishers, 1984), 8; David Halbertstam, *The Best and the Brightest* (New York: Random House, 1972), 367–68; Richard Kohn, chief of Air Force history, interview with author, June 1986.

6. For especially sharp criticism of the airmen, see Hanson Baldwin, "Introduction," in Jack Broughton, *Thud Ridge* (Philadelphia, Pa.: J. P. Lippincott, 1969), 12–13; and Dana Drenkowski, "Operation Linebacker II," *Soldier of Fortune*, September 1977.

7. This aircraft was poorly designed, having essentially no backup for its vital hydraulic controls. Of 617 US Air Force aircraft lost over North Vietnam, 280 were F-105s. McCrea, "Fixed-Wing Aircraft Losses," 6–47. In addition to a total of 334 F-105 combat losses in Southeast Asia, there were 63 operational losses. John Granville, "Summary of USAF Aircraft Losses in SEA," Tactical Air Command study, 1974, 22, 36, 57 [AFHRC-K417.042-16].

8. Broughton, *Thud Ridge*, 22, 96; William W. Momyer, *Air Power in Three Wars* (Washington, D.C.: Department of the Air Force, 1978), 126.

9. This was half of North Vietnam's MiG-21 inventory. R. Frank Futrell et al., eds., *Aces and Aerial Victories: The United States Air Force in Southeast Asia, 1965–1973* (Washington, D.C.: Government Printing Office, 1976), 35–42.

10. The Navy MiG kill ratio in Vietnam was 3.86:1 (54 MiGs destroyed) and the Air Force's was 2.15:1 (129 MiGs destroyed). "Southeast Asia Air-to-Air Combat," *Armed Forces Journal International*, May 1974, 38. In World War II, USAAF fighters had a 3.55:1 edge in air-to-air combat against Germany and 4.25:1 against Japan. The Navy and Marine Corps' ratio against Japan was 12.97:1. United States Army Air Forces, *Army Air Forces Statistical Digest: World War II* (Washington, D.C.: Office of Statistical Control, 1945), 255–61, 263–68; Adm Louis E. Denfeld, chief of naval operations, US Navy, address on the occasion of the 37th anniversary of naval aviation, 9 May 1949 [NHC]. In the Korean War, US Air Force fighter pilots ran up a 6.82:1 score of victories to losses in air-to-air combat. Larry Davis, *MiG Alley: Air to Air Combat Over Korea* (Carrollton, Tex.: Squadron Signal Publishers, 1978), 70; *USAF Credits for the Destruction of Enemy Aircraft Korean War*, USAF Historical Study no. 81 (Maxwell AFB, Ala.: Albert F. Simpson Historical Research Center, Air University, 1975).

11. A further 15 percent fell to SAMs, 7 percent to MiGs, 2 percent to friendly causes, and 10 percent to unknown causes. McCrea, "Fixed-Wing Aircraft Losses," 6-29, 6-46, 6-55; Granville, "Summary of USAF Aircraft Losses," 11.

12. Nordeen, *Air Warfare in the Missile Age*, 13; Paul Burbage et al., "The Battle for the Skies Over North Vietnam," in *Air War—Vietnam* (Indianapolis, Ind.: Bobbs-Merrill Co., Inc., 1978), 224; Schemmer, "Vietnam Casualty Rates," table 351; Institute for Defense Analyses, Jason study, "The Bombing of North Vietnam," December 1967, 2:49 [Box 247, Lyndon B. Johnson Library, Austin, Tex.].

13. Report of the Central Intelligence Agency, "The Effectiveness of the Rolling Thunder Program in North Vietnam: 1 January–30 September 1966," November 1966, A-2, A-16; CIA, "Report on Rolling Thunder," 1966, 6 [Both Box 221, Lyndon B. Johnson Library, Austin, Tex.]; Institute for Defense Analyses, Jason study, "The Bombing of North Vietnam," 3:49–50; Raphael Littauer and Norman Uphoff, eds., *The Air War in Indochina*, rev. ed. (Boston, Mass.: Beacon Press, 1971), 283.

14. McCrea, "Fixed-Wing Aircraft Losses," 2–3; Futrell, *Aces and Aerial Victories*, 4.

15. Cable to White House Situation Room, 12/16437 May, 1; Intelligence Memorandum, "Status Report on SAMs in North Vietnam," 29 June 1965, 1–2; and Memorandum, "CIA Appreciation of SA-2 Activity in North Vietnam During Late July," 1 August 1965, 1, in *CIA Research Reports: Vietnam and Southeast Asia, 1946–1976*,

ed. Paul Kesaris (Frederick, Md.: University Publications, 1983); Futrell, *Aces and Aerial Victories*, 5; Notes of Lyndon B. Johnson, White House meeting, 16 May 1965, 3 [Lyndon B. Johnson Library, Austin, Tex.]; Thomas D. Boettcher, *Vietnam: The Valor and the Sorrow* (Boston, Mass.: Little, Brown and Co., 1985), 232.

16. Apparently the Soviets fired 14 SA-2s at Francis G. Powers in 1960: 12 missed, one destroyed a MiG-19, and one got the U-2, R. A. Mason, ed., *War in the Third Dimension: Essays in Contemporary Air Power* (London: Brassey's, 1986), 105. John W. R. Taylor, ed., *Jane's All the World's Aircraft, 1967–68* (New York: McGraw-Hill Book Co., 1967), 521–22; C. M. Plattner, "SAMs Spur Changes, in Combat Tactics, New Equipment," *Aviation Week*, 24 January 1966, 26, 30; US Army, "Air Defense Artillery Reference Handbook," study, 1977, 18–19 [AUL-M39991-9]; Nordeen, *Air Warfare in the Missile Age*, 15; Laurence R. Jensen, "Use of Intelligence Information to Determine Countermeasures Requirements for the SA-2" (Thesis, Air Command and Staff School, Maxwell AFB, Ala., 1966), 9–10 [AUL-MU35582-7 J54u].

17. Jensen, "Use of Intelligence," 28–42; Richard Rash, "Electronic Combat: Making the Other Guy Die for *His* Country!" (Thesis, Air War College, Maxwell AFB, Ala., March 1983), 7, 92 [AUL-M43117-R224E]; Momyer, *Air Power*, 138.

18. McCrea, "Fixed-Wing Aircraft Losses," 2–10; Granville, "Summary of USAF Aircraft Losses," 10–11; US Pacific Fleet, "An Analysis of SA-2 Missile Activity in North Vietnam from July 1965 through March 1968," staff study 8-68, October 1968, 2 [NHC].

19. Momyer, *Air Power*, 136.

20. Nordeen, *Air Warfare in the Missile Age*, 16; Peter B. Mersky and Norman Polmar, *The Naval Air War in Vietnam* (Annapolis, Md.: Nautical and Aviation, 1981), 61; Bryce Walker, *Fighting Jets* (Alexandria, Va.: Time-Life Books, 1983), 112; M. J. Armitage and R. A. Mason, *Air Power in the Nuclear Age*, 2d ed. (Urbana, Ill.: University of Illinois, 1985), 108.

21. Nordeen, *Air Warfare in the Missile Age*, 18; CIA, "Effectiveness of Air Campaign," B-22; Maj Paul Burbage et al., "Air Superiority Tactics Over North Vietnam," (U) (Thesis, Air Command and Staff College, Maxwell AFB, Ala., 1975), 13 [AUL-M43034-2]. (SECRET—Information extracted is unclassified.)

22. Futrell, *Aces and Aerial Victories*, 4–5; Nordeen, *Air Warfare in the Missile Age*, 13; Gordon Swanborough and Peter M. Bowers, *United States Navy Aircraft Since 1911* (New York: Funk and Wagnalls Co., 1968), 177–78; Gordon Swanborough and Peter M. Bowers, *United States Military Aircraft Since 1908*, rev. ed. (London: Putnam,

1971), 267–69; Julian S. Lake and Richard V. Hartman, "Air Electronic Warfare," *U.S. Naval Institute Proceedings*, October 1976, 46; "US Marine Corps Forces in Vietnam: March 1965–Sept 1967, Historical Summary," vol. 2:36.

23. Nordeen, *Air Warfare in the Missile Age*, 16; Burbage, *The Battle for the Skies*, 240.

24. McCrea, "Fixed-Wing Aircraft Losses," 2-24, 2-29; USAF Pacific Command Scientific Advisory Group, "Shrike Missile Effectiveness under Rolling Thunder Operations" (Working paper 1-67, headquarters of the commander in chief Pacific, Scientific Advisory Group, January 1967), 1 [AUL-M42294-2]; USAF Pacific Command Scientific Advisory Group, "Shrike Effectiveness under Rolling Thunder Operation, First Quarter, 1967," (U) (Working paper 7-67, assistant for operations analysis, Headquarters Pacific Air Forces, April 1967), 1 [AUL-M38434-13 #67-9]. (SECRET—Information extracted is unclassified.) Nordeen, *Air Warfare in the Missile Age*, 18–19; Military Assistance Command, Vietnam, uncoordinated draft, "Linebacker Study," staff study, January 1973, 7 [AFHRC-K712.041-19]; Burbage, *The Battle for the Skies*, 247.

25. Report of Tactical Air Command, Directorate of Fighter Operations, "SEA Tactics Review Brochure," April 1973, 2:77–79 [AUL-M41737-283]; Nordeen, *Air Warfare in the Missile Age*, 19, 22; Swanborough and Bowers, *United States Military Aircraft*, 471; Momyer, *Air Power*, 130.

26. McCrea, "Fixed-Wing Aircraft Losses," 2-24; Nordeen, *Air Warfare in the Missile Age*, 23–24; Burbage, *The Battle for the Skies*, 240; Momyer, *Air Power*, 127; Lake and Hartman, "Air Electronic Warfare," 47.

27. Littauer and Uphoff, *The Air War in Indochina*, 283.

28. Schemmer, "Vietnam Casualty Rates," table 351.

29. Ibid.; Carl Berger et al., eds., *The United States Air Force in Southeast Asia: 1961–1973* (Washington, D.C.: Office of Air Force History, 1977), 116; Armitage and Mason, *Air Power in the Nuclear Age*, 92; James Coath and Michael Kilian, *Heavy Losses: The Dangerous Decline of America's Defense* (New York: Penguin Books, 1985), 136–37; Warren R. Young, *The Helicopters* (Alexandria, Va.: Time-Life Books, 1982), 140; Peter Mersky, *US Marine Corps Aviation: 1912 to the Present* (Baltimore, Md.: Nautical & Aviation, 1987), 244. In Vietnam, one helicopter was hit for every 450 sorties, one downed for every 7,000 sorties, and one lost for every 20,000 sorties. Peter Borgart, "The Vulnerability of the Manned Airborne Weapon System, Part 3: Influence on Tactics and Strategy," *International Defense Review*, December 1977, 1065.

30. Claude G. Morita, "Implication of Modern Air Power in a Limited War" (Report of interview with Gen John W. Vogt, Jr., commander, Seventh Air Force, Office of Pacific Air Forces History, 29 November 1973), 23–24 [AUL-M38245-228]; John A. Doglione, "Airpower and the 1972 Spring Invasion," *Air War—Vietnam*, 142, 197; Nordeen, *Air Warfare in the Missile Age*, 64; G. H. Turley, "Time of Change in Modern Warfare," *Marine Corps Gazette*, December 1974, 18; Center for Naval Analyses, "Documentation and Analysis of U.S. Marine Corps Activity in Southeast Asia: 1 April–31 July 1972," 1:110–11 [Marine Corps Historical Center]; Lake and Hartman, "Air Electronic Warfare," 47.

31. Doglione, "Airpower and the 1972 Spring Invasion," 132; Berger, *The USAF in SEA*, 168; Nordeen, *Air Warfare in the Missile Age*, 64; House, *Hearings before the Subcommittee of the Committee on Appropriations*, 93d Cong., 1st sess., 9 January 1973, 10; Center for Naval Analyses, "Summary of Air Operations in Southeast Asia: January 1972–31 January 1973," OEG/OP508N, January 1974, 4-17, 4-19.

32. Seymour Hersh, *The Price of Power: Kissinger in the Nixon White House* (New York: Summit Books, 1983), 506; Richard Nixon, *RN: The Memoirs of Richard Nixon* (New York: Grosset & Dunlap, 1976), 606–7.

33. Guenter Lewy, *America in Vietnam* (New York: Oxford University, 1978), 410; Hersh, *The Price of Power*, 526.

34. TAC, "SEA Tactics Review Brochure," II, 68.

35. Guided weapons were expensive, limited by the weather, and few in number. Directorate of Operations Analysis, Headquarters Pacific Air Forces, Project Contemporary Historical Examination of Current Operations Report, "Linebacker: Overview of the First 120 Days," 27 September 1973, 21, 27 [AUL-M38245-221]; Nordeen, *Air Warfare in the Missile Age*, 59, 63. One problem encountered with the ECM pods was that they created interference with the electro-optical guided bomb (EOGB) guidance system. A wire screen quickly solved that problem. Patrick J. Breitling, "Guided Bomb Operations in SEA: The Weather Dimensions, 1 February–31 December 1972," Contemporary Historical Examination of Current Operations Report, 1 October 1973, 3, 24 [AUL-M38245-223]; Jeffrey P. Rhodes, "Improving the Odds on Ground Attack," *Air Force Magazine*, November 1986, 48; Delbert Corum, "The Tale of Two Bridges," in *Air War—Vietnam*, 85–86; Morita, Vogt interview, 6.

36. Momyer, *Air Power*, 129; Military Assistance Command, Vietnam, "Linebacker Study"; Nordeen, *Air Warfare in the Missile Age*, 24; Senate, Committee on Armed Services, *Hearing Fiscal Year 1974*

*Authorization*, 92d Cong., 2d sess., 13–20 March 1973, pt. 6:4275.

37. TAC, "SEA Tactics Review Brochure," II, 78. During the period of 10 May through 10 September 1972, the United States lost 63 fixed-wing aircraft in combat over the North: 21 to AAA, 22 to MiGs, and 20 to SAMs.

38. Military Assistance Command, Vietnam, "Uncoordinated Draft," 7, chap. 8; Burbage, *The Battle for the Skies*, 267; Directorate of Operations Analysis, "Linebacker," 70–72; DOD, OAD, "US Aircraft Losses in SE Asia," October 1973, table 351, 5; R. Mark Clodfelter, "By Other Means: An Analysis of the Linebacker Bombing Campaigns as Instruments of National Policy" (Master's thesis, University of Nebraska, 1983), 77; Center for Naval Analyses, "Summary of Air Ops in SEA: Jan 72–Jan 73," 4-1, 4-8, 4-19, and 4-23.

39. Marvin and Bernard Kalb, *Kissinger* (Boston, Mass.: Little, Brown and Co., 1974), 412; Clodfelter, "By Other Means," 105, 111; W. Hays Parks, "Linebacker and the Law of War," *Air University Review* 34 (January–February 1983): 16; Nixon, *Memoirs*, 734.

40. Broughton, *Thud Ridge*, 36.

41. Briefing Books IV (U), Headquarters US Air Force, details on the Linebacker II missions, 2 vols., December 1972 [AFSHRC-K143.042-12]. (SECRET—Information extracted is unclassified.)

42. Norman Polmar, ed., *Strategic Air Command: People, Aircraft and Missiles* (Annapolis, Md.: Nautical & Aviation, 1979), 126; Granville, "Summary of USAF Aircraft Losses," 18; James McCarthy and George Allison, *Linebacker II: A View from the Rock* (Maxwell AFB, Ala.: Airpower Research Institute, 1979), 12; Karl Eschmann, "The Role of Tactical Air Support: Linebacker II" (Thesis, Air Command and Staff College, Maxwell AFB, Ala., 1985), 70–72 [AUL-M43122 E741r].

43. Eschmann, "The Role of Tactical Air Support," 49, 70-72; McCarthy and Allison, *Linebacker II*, 86. On these first three missions, 1.6 percent of the "Ds" and 4.9 percent of the "Gs" went down per sortie. In the entire 11-day campaign, the "Ds" suffered 1.8 percent and the "Gs" 2.7 percent losses. About 10 percent of the missiles fired against the "Gs" impacted, whereas only 3 percent of those fired against the "Ds" did likewise. Headquarters US Air Force, Briefing Books, December 1972; Briefing, Headquarters Pacific Air Forces, "Operations Analysis: Linebacker II Air Operations" (U), 31 January 1973 [AFHRC-K168.06-232]. (SECRET—Information extracted is unclassified.) The gunners on B-52Gs were stationed in the tail, where they used either electronic or visual sighting. McCarthy and Allison, *Linebacker II*, 70; Eschmann, "The Role of Tactical Air Support," 49.

44. This policy quickly changed beginning with the second wave on

the second day. McCarthy and Allison, *Linebacker II*, 46–47.

45. Robert Clement, "A Fourth of July in December: A B-52 Navigator's Perspective of Linebacker II" (Thesis, Air Command and Staff College, Maxwell AFB, Ala., 1984), 18, 49 [AUL-M43122 C626f]; McCarthy and Allison, *Linebacker II*, 30, 32.

46. Headquarters USAF, "Linebacker USAF Bombing Survey," 1973, 35 [AFHRC-K717.64-8]; TAC, "SEA Tactics Review Brochure," II, 77; Eschmann, "The Role of Tactical Air Support," 60.

47. Eschmann, "The Role of Tactical Air Support," 60, 63; Clodfelter, "By Other Means," 121.

48. TAC, "SEA Tactics Review Brochure," II, 76.

49. Strategic Air Command Briefing, subject: Chaff Effectiveness in Support of Linebacker II Operations, March 1973 [AFHRC-K168.06-223].

50. Ibid.

51. TAC, "SEA Tactics Review Brochure," II, 76.

52. "The Battle for the Skies Over North Vietnam: 1964–1972," 94 [AFHRC-K239.043-14].

53. SAC, "Chaff Effectiveness," March 1973; TAC, "SEA Tactics Review Brochure," II, 76.

54. SAC, "Chaff Effectiveness," March 1973; for a general discussion of the changes, also see Clement, "A Fourth of July in December," 49; Eschmann, "The Role of Tactical Air Support," 75–76; McCarthy and Allison, *Linebacker II*, 97, 121; History, 388th Tactical Fighter Wing, October–December 1972, 27, 32-33.

55. B-52s flew 708, F-111s 148, A-7s 226, and F-4s 283 effective sorties. Headquarters US Air Force, Briefing Books, II.

56. During periods of limited visibility, the TAC fighters scored some remarkable successes, most notably hitting two especially difficult targets, the Hanoi thermal plant and Radio Hanoi. The latter, protected by a 25-foot-high and 10-foot-thick blast wall, had survived the bombing of 36 B-52s. F-4s got four laser-guided bombs inside the walls and destroyed the target. Clodfelter, "By Other Means," 120; assistant chief of staff, Intelligence (ACSI), "Linebacker II: 18–29 Dec. 72" (U), supporting document III-K1 [AFHRC-TS-HOA-74-197]. (TOP SECRET—Information extracted is unclassified.)

57. History, Air Force Intelligence Service, 1 July 1972–30 June 1973: Linebacker II Summary III, K2; Center for Naval Analyses study, "U.S. Navy, Marine Corps, and Air Force Fixed-Wing Aircraft Losses and Damage in Southeast Asia (1962–1973), Part I: List of Aircraft Lost," report no. CRC 305 (Alexandria, Va.: Defense Documentation Center, 1977), 191–93, 223, 488–92 [AUL-M31914-22 #305 (a) v. I]. Eschmann, "The Role of Tactical Air Support," 103–

4, lists 30 aircraft destroyed, including three lost in accidents. Futrell, *Aces and Aerial Victories*, 17, states that 27 US Air Force aircraft were lost. The North Vietnamese claimed 81 United States aircraft (34 B-52s). Gareth Porter, *A Peace Denied: The United States, Vietnam, and the Paris Agreements* (Bloomington, Ind.: Indiana University, 1975), 161–62; Richard Holloran, "Bombing Halt Brings Relief to B-52 Crews in Guam," *New York Times*, 2 January 1973, 3. Drenkowski, "Operations Linebacker II," pt. 2, 55, says that 22 to 27 B-52s were destroyed.

58. Clodfelter, "By Other Means," 108; Clement, "A Fourth of July in December," 47.

59. Headquarters US Air Force, Briefing Books, I and II.

60. Eschmann, "The Role of Tactical Air Support," 108; Berger et al., *The USAF in SEA*, 60; Drendel, *And Kill MiGs*, 47, 73; SAC, "Chaff Effectiveness," March 1973; McCarthy and Allison, *Linebacker II*, 65, 116; Futrell, *Aces and Aerial Victories*, 125.

61. Eschmann, "The Role of Tactical Air Support," 46.

62. Center for Naval Analyses, "Summary of Air Ops SEA: Jan 72–Jan 73," 4–17. The North Vietnamese did not have the most modern equipment; in the 1973 Middle East War the Egyptians and Syrians inflicted heavy losses on Israeli aircraft with Soviet SA-3 and SA-6 missiles and ZSU-23-4 guns, equipment not employed in the Vietnam War. See chapter 4. The North Vietnamese may have improved and manned their defenses without the help or knowledge of the Soviets. Porter, *A Peace Denied*, 161; Jon M. Van Dyke, *North Vietnam's Strategy for Survival* (Palo Alto, Calif.: Pacific Books, 1972), 61, 217.

63. On the third day of the campaign, a SAC commander ordered a search for North Vietnamese SAM storage facilities. Within 18 hours, the intelligence people began to find them, whereupon SAC requested JCS permission to bomb them. Permission for all but one was forthcoming, although it took another 24 to 36 hours. As a result, these targets were not hit until 26 December. McCarthy and Allison, *Linebacker II*, 97–98.

64. Ibid., 155; Eschmann, "The Role of Tactical Air Support," 94; George Allison, "The Bombers Go to the Bullseye," *Aerospace Historian*, December 1982, 233; History, 388th Tactical Fighter Wing, October–December 1972.

65. While several helicopters and transports were destroyed on the ground, intelligence claimed that only two to three MiG-21s were damaged. The bulk of the bombs fell on railroad yards (44 percent) and storage facilities (30 percent). ACSI, "Linebacker II"; Headquarters USAF, "Linebacker USAF Bombing Survey," 3, 14, 16–17, 40–43.

66. Clodfelter, "By Other Means," 127. The airmen had also run out of worthwhile targets in the Hanoi-Haiphong area. McCarthy and Allison, *Linebacker II*, 163.

67. It would be ahistorical to maintain, however, that the same terms could have been reached in October.

68. Momyer, *Air Power*, 126; Senate, *Fiscal 1974 Authorization Hearing*, pt. 6:4253.

69. American antiaircraft gunners tracked very few targets during the course of the Vietnam War. There were at least two incidents of North Vietnamese aircraft attacking American ground or sea forces. Although some US Army AAA units served in the war, none fired their weapons against hostile aircraft. The Navy credits its gunners, however, with downing three North Vietnamese MiGs. The first fell to a Talos missile fired from the *Long Beach* in November 1968, the second to a Terrier fired by the *Sterett* on 19 April 1972, and the third to a Talos fired by the *Chicago* on 9 May 1972. History, Seventh Fleet, 1972, enclosures 1, 20, 25 [NHC]; McCrea, "Fixed-Wing Aircraft Losses," 2-30.

## CHAPTER 4

# RECENT EXPERIENCE

Recent experience offers several instances where ground-based air defense systems made the difference. This chapter discusses the Arab-Israeli War, American air strikes in the Middle East, Indian-Pakistani Wars, the Falkland War, and other recent and ongoing conflicts.

## Arab-Israeli Wars

Of the numerous non-American conflicts since 1945, none have stirred more military interest than those between Arabs and Jews. Their number, Western sympathies, Israeli successes against great odds, and the employment of modern equipment on a large scale are all factors which generate this interest. Israeli predominance in the air attracts particular attention. For Israeli, air power plays and continues to play a vital role in their successful military record.

### 1948, 1956, and 1967

Although Arab and Jew have been fighting each other for a long time, the airmen's interest focuses on their conflicts since 1967, in which air power has played a significant role. Both sides employed aircraft in the 1948 and 1956 wars, but these forces consisted of small numbers of obsolete, or obsolescent, aircraft. In 1956 the Israelis lost 10 to 15 aircraft out of a total inventory of 136–155, most to ground fire, and claimed eight aerial victories.[1] In the 1967 and 1973 conflicts, however, the combatants used modern equipment and air power became critical, if not predominant.

It can be argued that air power won its most striking victory of all time in the June 1967 war. Preemptive strikes by the Israeli Air Force (IAF) on the first day destroyed the bulk of the numerically superior Arab air forces on the ground, permitting Israeli armor and close-support aircraft to decisively crush the numerically superior Arab ground forces. On that first day, the IAF destroyed 85 percent of the Egyptian Air Force and a total of 410 Arab aircraft in exchange for 19 aircraft lost (all but two or three to ground fire). This short, sharp war cost the Israelis a total of 40 to 50 aircraft (all but three to 12 to ground fire). In contrast, the Arab air forces lost about 450 aircraft, mostly on the ground, including 60–79 to Israeli aircraft and about 50 to Israeli ground-based air defenses.[2]

Although the Egyptians had 18 to 25 batteries of SA-2s, those batteries had no direct effect on the battle. Their SAM operators fired perhaps 12 missiles but registered no kills, although possibly one hit. The unclassified sources do not mention a breakdown of Israeli credits for their surface-based air defense systems, but apparently an Israeli Hawk downed an IAF A-4 on 5 June. The damaged fighter-bomber apparently penetrated a restricted area around an Israeli nuclear facility.[3]

## 1967–73

The Israelis gained a phenomenal military victory and new territories in the 1967 War, but they did not win peace. Soviet resupply of her Arab clients led to a drawn-out land and air war of attrition along the Suez Canal, the new border between Egypt and Israel. Between July 1967 and January 1970, the IAF lost 15 aircraft (13 to ground fire) while it claimed 74 Egyptian and Syrian aircraft. In September–October 1969, the IAF took out the Egyptian SAMs. In

January 1970 the Israelis received US ECM pods and, within three months, neutralized the Egyptian air defense system by destroying three-fourths of its early warning radar.

The Soviets countered in early 1970 by sending more missiles, including the SA-3, to Egypt. Although the SA-3's range was about one-third to one-half that of the SA-2 (slant range of 13–17 miles compared to SA-2's slant range of 25–30 miles), the former could operate against lower-flying aircraft. The missiles became operational in April 1970, and by the end of June the Egyptians had a total of 55 SAM batteries. Soviet technicians, operators, and pilots bolstered the Egyptian air defenses, which, in essence, they took over. The air war heated up in late June when SAMs downed three IAF aircraft in one week. Meanwhile, the IAF attacked the Egyptian SAMs and destroyed five batteries. On 8 July 1970 the two opponents agreed to a cease-fire; and although the battle subsided, tensions remained and the lull permitted the Egyptians to rebuild their defenses along the canal. In the war of attrition (July 1967 to May 1973), the Israelis lost 27 aircraft (25 to ground fire) and the Arabs lost 162 aircraft (13 to Hawks and 24 to 37-mm and 40-mm guns).[4]

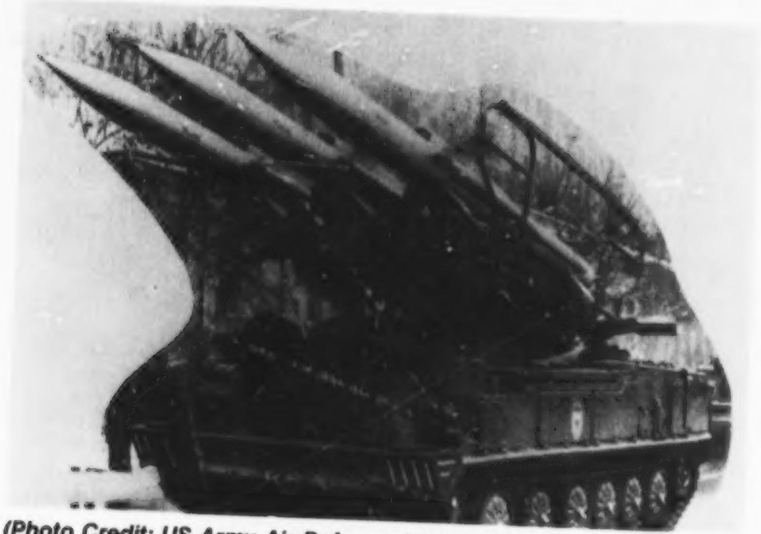
## 1973

The joint Egyptian-Syrian attack on Israel on 6 October 1973 took both the world and the Israelis by surprise. Because of the overwhelming superiority of the IAF, no one expected the Arab armies to win; therefore, no one expected them to attack. Conventional wisdom held that air superiority was vital to victory. After all, aviation had ruled the battlefield since 1939, or, put another way, victory was possible only under friendly or at least neutral skies. This view conveniently overlooked the various guerrilla wars and most especially the Vietnam War. During the first days of the conflict, the two Arab states used their air forces sparingly. They relied primarily on ground-based air defense systems and were modest in their air plans, attempting only to gain local and limited air superiority. On day one, the Egyptians flew 200–240 sorties while their armies advanced under a protective umbrella of surface-based air defense weapons.

This umbrella was massive, mixed, and mobile. The Egyptians emphasized their surface-based air defense force (formed as a separate service in 1968), which has three times as many personnel as did their air force and which comprised one-fourth of their total armed forces. The Syrian air defense was smaller in size, but much denser because its battlefield was smaller. The Syrians manned perhaps 47 SAM batteries (32–35 SA-6s and the rest SA-2s and SA-3s), while the Egyptians operated 150 batteries, of which 46 were SA-6s.[5]

The Arabs fielded not only a large number but also a great assortment of Soviet equipment. The vast number of guns was imposing, although the most modern was the small number of four-barrel 23-mm ZSU-23-4. The missile arsenal included the SA-2 and SA-7 employed in Vietnam, the SA-3 employed in the war of attrition, and a new missile, the SA-6 (fig. 75). The Arab air defense system was more than just large and varied, for, unlike the immobile North Vietnamese defenses (except for light AAA and SA-7s), the Arab air defenses could move, as the ZSU-23-4 and SA-6 were vehicle mounted, and the SA-7 and SA-9 were man portable. What must be emphasized is that the impact of the Arab air defenses came from the combination of numbers, mixture, mobility, and modernity, as the IAF soon found out.[6]

The SA-6, the most modern of these weapons, had been observed in 1967 but had not been seen in action. It was a relatively small, smokeless missile weighing about 1,200 pounds, permitting three to be mounted on a converted (PT-76) tank chassis. The missile was faster (2.5–2.8 Mach)

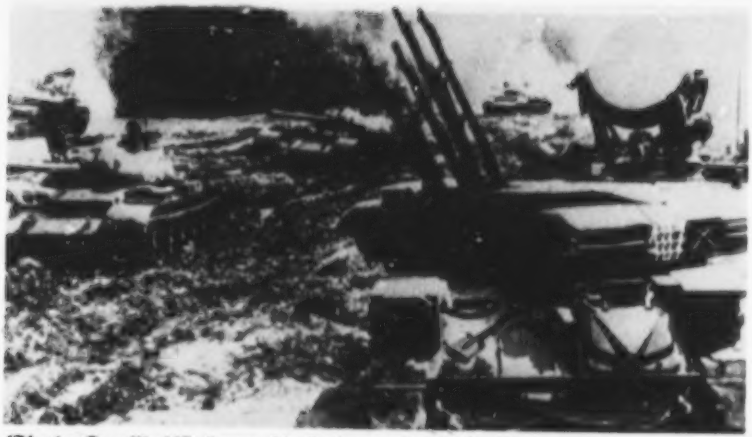


(Photo Credit: US Army Air Defense Artillery Museum)

Figure 75. Soviet SA-6.

and much more sophisticated than the other Soviet SAMs, as it used radar to guide its initial flight and rapidly changed frequencies, and then homed in on its prey using heat-seeking sensors. (The SA-6 used a filter, as did the SA-7, to counter the use of flares intended to decoy its infrared sensor.) Although its 17–25 mile slant range is comparable to the SA-2's and SA-3's, the SA-6 could kill aircraft flying at low altitudes. Therefore, the combination of newness, mobility, high speed, sophisticated guidance, and low-altitude capability gave the SA-6 a powerful potential. While it did not produce the 97-percent kill rate promised by the Soviets, it downed many aircraft and forced IAF aircraft into Arab AAA, especially the ZSU-23.[7]

The ZSU-23-4 (fig. 76) was a very effective AAA piece. Mounted on a modified PT-76 tank chassis, its four 23-mm barrels could fire at a maximum rate of 4,000 rounds per minute, although gunners never just held the trigger



*(Photo Credit: US Army Air Defense Artillery Museum)*

**Figure 76. Soviet ZSU-23-4.**

down but instead were trained to fire in short bursts of 75 or so rounds. A radar with a 12-mile range directed the guns, which could reach an effective range of about 4,000 feet. There were also optical sights. Similar to the SA-6, the weapon's chief assets were its low-altitude capability, mobility, and the fact that the West had not previously observed it in action.[8]

Following the initial Arab assault, as expected, the Israelis quickly launched tank and aircraft counterattacks to blunt the advance of the invading Arab armies, to succor the outnumbered and outgunned forward defenders, and to shield Israel's mobilization. However, Israel's tankers, airmen, equipment, and tactics failed against Arab missiles and guns. On the Suez front, the IAF lost four aircraft in their first strike; and on the Golan Heights front, they lost four out of four aircraft on the first wave and two of four aircraft on the second wave. Some claim that Arab gunners downed as many as 30 to 40 Israeli aircraft on the first day of the war.

During the first three days, the IAF lost dozens of aircraft at the Suez front, perhaps as many as 50. These heavy losses (twice the rate of the 1967 war) shocked the Israelis, who for the moment stopped flying within 10–15 miles of the Suez Canal. But the grave military situation required the IAF to continue its efforts, especially on the critical Syrian front. During the first week, the IAF lost a total of 78–90 aircraft, a sizable percentage of their force and of what were to be their overall losses.[9]

The SA-7 had little direct impact on the battle and probably served most as a nuisance to the Israelis and a morale booster to the Arabs. Despite an infrared (IR) filter, the shoulder-fired SAM downed only two fixed-wing aircraft, although it damaged 30 others. Aircraft could outrun and outmaneuver the missile, as US airmen had proved the year before. In addition, the SA-7 lacked killing power; it hit aircraft in the tail, where its small warhead did not inflict serious damage. A vehicle-mounted arrangement, the SA-8 fitted with eight SA-7s, was no more effective.[10]

On the other hand, the SA-6 proved especially effective both directly by destroying a sizable proportion of IAF aircraft and indirectly by forcing Israeli aircraft into Arab AAA fire. The SAM's rapid speed and its new and changing frequencies were difficult to counter. The overconfidence of the Israelis, their neglect of ECM (at one point, the IAF stripped ECM from their aircraft for greater economy, speed, and maneuverability), and US restrictions on ECM sales left the IAF in a serious bind. Israeli improvisation was speedy and effective, yet costly.[11]

The IAF used a variety of means to deal with the SAM threat. To spoof heat-seeking missiles, the IAF employed aircraft maneuvering, such as violent maneuvers, turning toward the missile, to present the IR seeker a "cold side," and maneuvering aircraft to cross in the sky creating a "hot spot." In addition, Israeli airmen dropped flares and even jettisoned fuel and then ignited it in order to decoy the heat-seeking missiles. Spotters in helicopters warned pilots of missile launches. The IAF also used chaff, first carried in speed brakes, later in a more conventional manner, improved American ECM pods, and standoff jammers operating from the ground, helicopters, and transports.

In addition, the Israelis directly assaulted the SA-6s. The SA-6's low initial trajectory encouraged the IAF to divebomb the SAMs from very steep angles: desperate measures improvised for a desperate situation. The IAF also fired Shrike antiradiation missiles.[12]

The Israelis turned around the air war, and to a degree the ground action, by taking out the Arab SAMs. Concentrating first on the Syrians, the IAF destroyed half of their SAMs in four days. One source claims that the Israelis knocked out a Syrian control center which seriously hampered the Syrian missile defenses. The Syrians were defeated and only political restraints prevented a much greater Israeli victory.[13]

The solution to the IAF's problem on the Egyptian front came from an unexpected source, the Israeli Army. The Egyptians made one major thrust from their formidable position along the canal and suffered a decisive defeat on 14 October in the largest tank battle since World War II. The Israelis quickly followed up their tactical victory. In the early morning of 16 October, Israeli forces crossed the canal and in short order created havoc in the Egyptian Army. By midday, the Israelis had destroyed four SAM sites; and by the next morning, the IAF was operating in full support of the ground forces. In reverse of the accepted practice, the Army made it possible for the Air Force to operate. The Israelis now had the initiative and could easily have inflicted an overwhelming defeat on the Egyptians. But, the major powers intervened, which led to a cease-fire on 22 October. The Israelis won the war and in the process destroyed approximately 40 of the 55–60 SAM batteries that the Egyptians had in action. This destruction was inflicted by the IAF, as well as by Israeli ground forces.[14]

Nevertheless, the ground-based air defenses took a substantial toll. The combatants lost about the same number of aircraft to SAMs and flak, the Arabs 40 to 75 (one or two dozen to Hawks) and the Israelis perhaps 82 to 100.[15]

The ground defenses also claimed a number of friendly aircraft. Israeli gunners apparently downed two of their own aircraft, which were probably Mirages mistaken for the same type aircraft the Egyptians received from the Libyans. The Arabs destroyed 45 to 60 of their own. On 8 October, for example, Syrian SAMs destroyed 20 Iraqi MiGs, while Egyptian SA-6s may have downed 40 Egyptian aircraft. Thus, the Arab SAMs destroyed more Arab aircraft (45–58) than Israeli aircraft (39–44). This accounted for about 10–12 percent of total Arab losses.[16]

Helicopters again proved vulnerable. Israeli air and ground defenses devastated an Egyptian commando strike carried out by approximately 50 Mi-8 helicopters on the first day of the war, downing 20–35 of them. The Israelis claimed the destruction of 35 Egyptian choppers in the first days of the war. An Egyptian attack on the critical Israeli canal bridge on 18 October ended with all five helicopters downed. On the Arab side, SA-7s claimed six IAF rotary-wing aircraft.[17]

The IAF clearly won the air war, destroying about 450 Arab aircraft, while losing about 107 aircraft in combat, 115 overall. Compared to the 1967 war, the Arabs lost about the same number of aircraft, although many more in the air, while the Israelis lost twice as many. On a sortie basis, however, IAF losses actually declined from 4 percent in 1967, to just over 1 percent in 1973. Arab losses in 1973 were just under 5 percent.[18]

Although the IAF beat the Arab air forces in the air, it failed to use air power as it had in the 1967 war. Close air support (CAS) proved limited and disappointing, especially in the first three critical days of the war. One study stated that aircraft did not unequivocally damage or destroy one tank. Even if this decline in CAS effectiveness is overdrawn, air power clearly influenced the war less in 1973 than it had in 1967. A dense, mobile, mixed, surface-based air defense system thwarted possibly the best-trained and highest-motivated air force in the world and inflicted severe losses on it. Just as American airmen underestimated North Vietnamese air defenses, so had the Israeli airmen underestimated Arab air defenses. Both paid the price. The 1973 war seemed to indicate that the balance between the offense and defense (specifically aircraft versus ground defenses) had swung in favor of the latter. Aircraft appeared to have lost much of their battlefield dominance.[19]

## 1982

The IAF action in Lebanon in the summer of 1982 altered the apparent shift of superiority toward ground defenses. Lebanon existed in a state of chaos from the occupation by militias of right and left, Palestine guerrillas and Syrians, and from fighting among these groups and between them and the Israelis. The Syrians rebuilt their military forces from the defeat of the 1973 war and, in so doing, almost tripled their ground-based air defenses, increasing them from 30 to 80 batteries and manning them with their best personnel. In late April 1981 the Syrians moved 19 batteries of missiles, including SA-6s, into Lebanon's Bekaa Valley. Here the Syrians established a dense and, what appeared from the record of the 1973 war, formidable air defense system.[20]

In early June 1982 the Israelis invaded Lebanon, primarily fighting the Palestine guerrillas but also engaging the Syrians. The Israelis battered the latter, despite their large arsenal of apparently modern Soviet equipment and the "lessons" of the 1973 war. In this brief but intense action the Israelis won a lopsided victory, destroying 80 to 90 Syrian aircraft* and 19 to 36 batteries of missiles, for the destruction of three to six Israeli aircraft.[22]

---

*Israelis ground fire downed at least one Syrian jet (a Vulcan gun got an Su-7) and two helicopters.[21]

On 9 June the IAF took on the Syrian air defenses in the Bekaa Valley with a complex yet carefully planned, coordinated, and executed attack. The Israelis used air- and ground-launched drones as decoys to activate Syrian radar. This allowed the Israeli EC-135s to obtain the location and frequency of the Syrian radars and in turn to rapidly relay this information to strike elements. The Israelis thereby coupled real-time intelligence with rapid response to give their pilots precise locations of the SAMs and accurate tuning information for their jamming equipment. In the electronics war, the IAF used ECM pods, chaff rockets, possibly chaff from drones, and standoff jammers in CH-53, Boeing 707, and Arava transports. The Israeli airmen employed diversionary tactics, precise timing, sharply executed low-level tactics, and weapons such as ARMs, standoff weapons, iron bombs, and cluster munitions. In addition, the Israelis used a new surface-to-surface ARM, the Wolf missile. Ground forces fired artillery, launched ground assaults along the front, and just before the air attack took out a control center with a commando raid. The Syrians did not help their own cause, as they failed to dig in, poorly sited their radar, and ignited smoke screens that guided rather than confused the IAF. On the first day, the IAF destroyed 17 missile batteries and severely damaged two others. The Syrians pushed more SAM units into the Bekaa Valley, but to no avail. On the second day of the action, the IAF destroyed 11 more missile batteries. On 24 July the Israelis knocked out three batteries of SA-8s. A few days later, they destroyed some SA-9s (fig. 77). Reportedly, the IAF destroyed four SA-9 batteries in September.[23]

## American Air Strikes in the Middle East, 1983-86

American strikes in the Middle East a little over a year later were much less successful. The United States intervened in Lebanon in 1983 and that December the US Navy

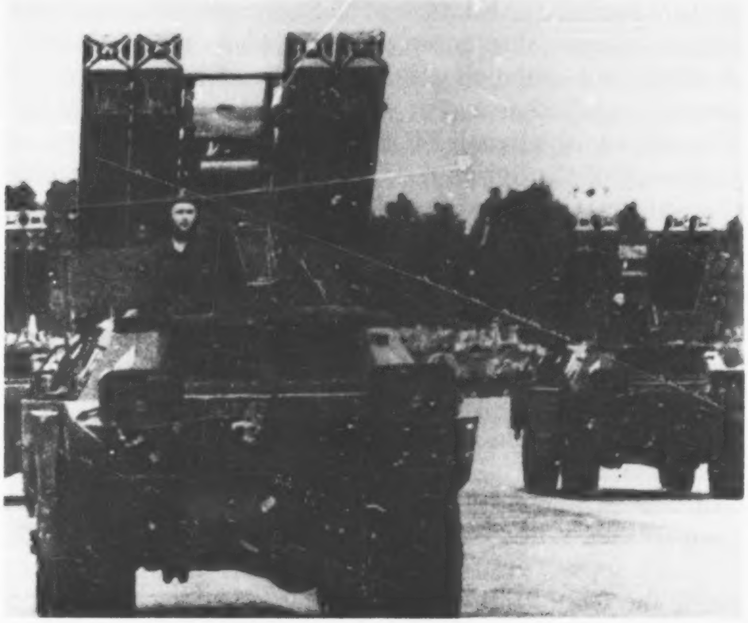


Figure 77. The Soviet SA-9 is a mobile version of the SA-7 missile.

responded to Syrian firing on American reconnaissance aircraft with 12 A-7Es and 16 A-6Es. The naval aviators used tactics proven in Vietnam: they penetrated at 20,000 feet then descended to 3,000 feet for their attacks. To counter Syrian heat-seeking missiles, they dropped numerous decoy flares—but to little effect. The American flyers encountered intense defenses, more than expected, and Soviet SA-7 and SA-9 missiles had been modified to counter the decoy flares. The Syrians launched 40–50 SAMs, which downed one A-7 and one A-6 and damaged another A-7. While the Navy blamed the losses on changes in Soviet missile sensors, the Israelis criticized American planning, tactics, and experience. Later Syrian fire against US aircraft was met by ship fire.[24]

This less than satisfactory experience jarred the Americans and probably influenced the next US air operation, the April 1986 raid on Libya. One factor driving American planning was to avoid the SA-7s, which meant operating at night. There were, of course, other reasons for night operations, such as achieving maximum surprise, avoiding a major engagement with Libyan air defenses, avoiding casualties to both Soviet advisers and Libyan civilians, and revealing as little American ECM as possible. But night operations also meant that only two American aircraft could be effectively used: the Air Force's FB-111 and the Navy's A-6. While the A-6s were aboard carriers cruising in the Mediterranean, the FB-111 bombers were stationed in Britain, 5,600 miles away (a 14-hour flight). The FB-111s would require aerial refueling because of the distance and government overflight restrictions.[25]

US airmen flew a large strike force of 32 bombers (18 FB-111s and 14 A-6s) supported by almost 70 aircraft. The large supporting force was required because Libyan air defenses were both large and sophisticated for a third world country. Besides MiGs, the defenses consisted of 100 batteries of SA-2s, SA-3s, and SA-6s (about 30 to 60 batteries were operational), as well as SA-5, SA-8, SA-9, and French Crotale missiles, and perhaps 450 AAA guns.[26]

The American aircraft successfully penetrated Libyan defenses, suppressing and evading fire from Libyan SAMs and AAA and encountering no aerial opposition. The airmen used low-level and high-speed tactics, the FB-111s at 400 feet and 500 knots, the A-6s as low as 200 feet and 450 knots, and they dropped both laser-guided and iron bombs. One FB-111 went down, the cause not publicly known. Although the Libyans received 30 to 45 minutes notice from Maltese air controllers that unidentified aircraft were heading for North Africa, apparently Libyan radar did not activate until about four minutes before the 2:00 A.M. attack. Standoff jamming by EF-111s and EA-6Bs, on board ECM, and about 50 antiradiation missiles almost completely nullified Libyan radar. The mission was both a technical and political success: the airmen got their bombs on target, losses were light, and since the air attack, there has been a lack of terrorist activity openly and directly associated with the Libyans. Thus, the 12-minute raid demonstrated that the American military could hit difficult targets despite distance and other natural obstacles as well as penetrate fairly numerous and sophisticated defenses with light losses.[27]

## Indian-Pakistani Wars

In September 1965 war erupted on the Asian subcontinent between India and Pakistan and burned itself out in 23 days. Both sides fielded small air forces equipped with a few modern aircraft (Indian MiG-21s and Pakistani F-104s), but most aircraft were at least a decade beyond their prime (Indian Hunters and Vampires and Pakistani F-86s).

Just as the ground war ended in a stalemate, so did the air war. But even at this writing (1988) it is difficult to sort out from the conflicting claims exactly what happened. The Pakistanis claim to have destroyed 110 Indian aircraft—35 in air-to-air combat, 32 by antiaircraft guns, and the rest in attacks on airfields. They admit to losing 19 aircraft, eight in air combat, two to their own AAA, and nine to other causes. The Pakistanis admit that Indian guns downed a few aircraft, but claim none of the F-86s engaged in almost 500 CAS sorties were lost, although 58 were damaged. The Indians claim 73 Pakistani aircraft destroyed and admitted losing 35. The Indians fired a few SA-2 missiles and claimed one C-130. The Pakistanis dispute this claim, stating that they did not lose a C-130 to the SAMs, and counter that the SA-2 got an Indian An-12 transport. The Pakistanis do admit that an SA-2 damaged an RB-57F at 52,000 feet.[28]

In December 1971 the two countries fought another brief (two-week) war. By this time both sides had upgraded their air forces in quality and quantity but still fielded forces that were relatively small and of mixed vintage. This war resulted in Pakistan's losing what is now Bangladesh.

Again the combatants' claims markedly conflict, and these differences remain along with the political problems. Indians claimed to have destroyed 94 Pakistani aircraft for the loss of 54 and stated that one aircraft fell to an SA-2 missile. The Pakistanis claimed the destruction of 104 Indian aircraft at the cost of 26 planes. They admit losing three to four aircraft to flak as well as two aircraft to friendly fire. The Pakistanis assert that 49 of their 104 kills were registered by AAA. Another source states that half of the lost Pakistani aircraft fell to ground defenses.[29]

## The Falklands, 1982

More recently, another brief campaign in a remote part of the world captured the public's attention. The Falklands campaign surprised the civilian and military alike because Argentina and Britain went to war, because Britain successfully liberated the islands over such a great distance, and because Argentina inflicted startling losses on the British forces. The conflict pitted a small, well-trained, and well-equipped modern force of a European nation operating 7,000 miles from home against a larger, less well-trained force with a mixture of old and modern equipment of a developing nation. It provides us with another look at air defenses in operation.

From the standpoint of the air war, the Argentines fielded an air force of mixed capabilities equipped with old Canberras (fig. 78) and A-4s, counterinsurgency Pucarás, and the more modern Mirages and Super Etendards. For ground-based defenses, the Argentines had, in addition to automatic weapons, British (Sea Dart, Seacat, and Blowpipe) and Franco-German (Roland) surface-to-air missiles.

Although the British used the old Vulcan bomber (fig. 79), their primary combat aircraft was the vertical-takeoff-

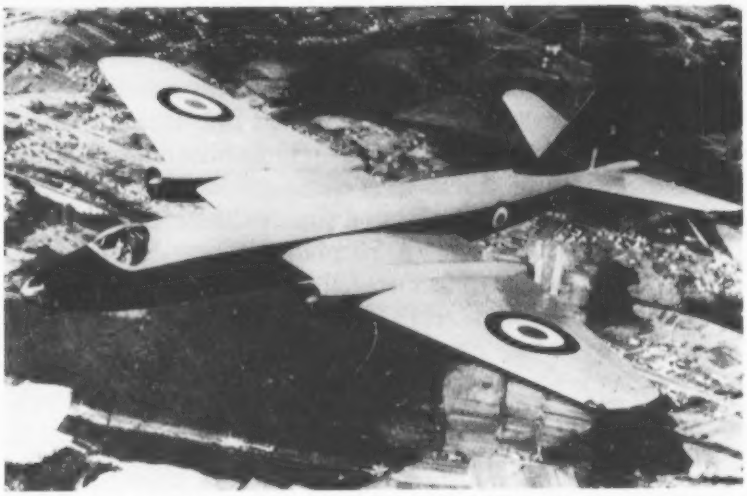


**Figure 78.** One of the ironies of the Falkland War was that the British faced their own equipment. One such example was Argentine use of the Canberra, shown here with RAF markings.

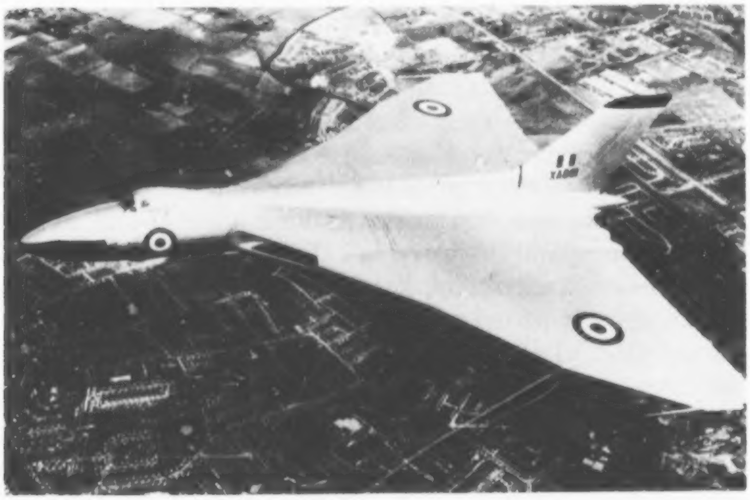


**Figure 79.** Although designed as a nuclear bomber, the Avro Vulcan saw its only combat in attacks on the Argentine airfield and radar site at Port Stanley.

and-landing Harrier (fig. 80). The Royal Navy ships operated a mixture of gun defenses and SAMs (Seacat, Seawolf, Sea Dart, and Seaslug). British troops ashore used three SAM systems: Blowpipe, Stinger, and Rapier.[30]

The Argentine air defense proved minimal against the British Harriers and helicopters. However, it should be quickly noted that, in contrast to the Argentine Air Force, which flew and fought without ECM, the British employed both airborne ECM (jammers aboard Vulcan bombers and chaff dispensers on Sea Harriers) and shipborne ECM (jammers and Corvus chaff rockets). The British used antiradiation missiles (Shrikes) against the main Falkland-based Argentine radar without success, but the missile did destroy one other radar set.[31] The Argentine air arms lacked similar weapons. Argentine fire destroyed 22 British aircraft, 13 of which were helicopters destroyed aboard ships sunk or

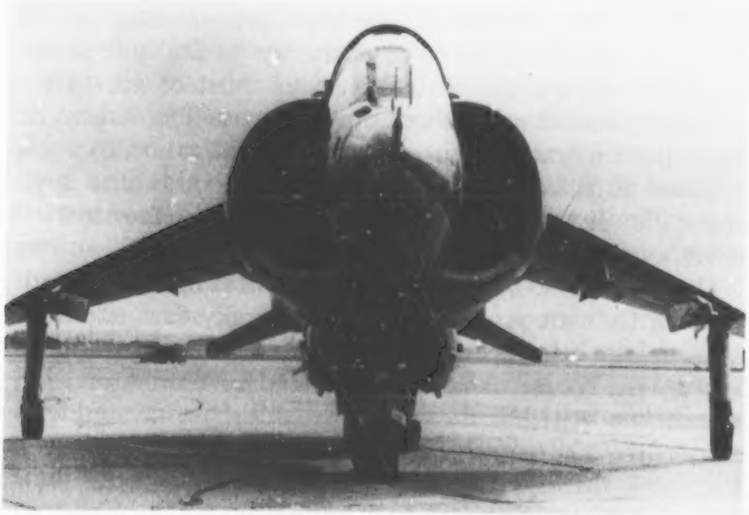


**Figure 80.** **The star of the air war in the Falkland Islands was the Hawker Siddeley Harrier. In the unique circumstances of that war, the vertical takeoff and landing aircraft proved more than a match for conventional jet aircraft.**

damaged by air attack. Argentine ground fire destroyed all but one of the remaining nine, a Scout helicopter downed by a Pucará. The British flew 2,000 sorties, but state that they lost only five Harriers in combat: one to a Roland missile, one to small arms, and three to 35-mm antiaircraft fire. Small arms or Blowpipe missiles accounted for three Gazelle helicopters. One source claims that the Argentines engaged two of their own helicopters—not unlikely, as both sides flew the same kinds of machines.[32]

The effectiveness of the Argentine Air Force provided one of the big surprises of the war, especially considering its limitations. The Argentine airmen flew mostly outdated aircraft during daytime, in clear weather, without ECM, and at the limits of their range. In addition, with the exception of five French-made Exocet missiles, they dropped gravity bombs on targets (mainly ships) that they had not been trained to engage. Nevertheless, they sank six ships and damaged perhaps eight others. British losses could have been far worse, but one-fifth, perhaps three-quarters, of the Argentine bombs failed to explode due to faulty fuze settings, defective fuzes or bombs, and most of all, to extremely low-level and short bomb releases. The Argentine pilots demonstrated their courage and dedication by their repeated attacks despite the formidable odds and high losses. For example, between 21 and 25 May they lost 19 aircraft on 117 sorties.[33]

The British also operated under a number of severe handicaps in the campaign. The British supply line stretched 7,000 miles between the Falklands and Britain, relieved only by the sparse, American-operated base on Ascension Island. The British had only two small carriers available to support the campaign. (The British planned to reduce even this small force. Thus, had the Argentines delayed their action, British difficulties would have been far greater.) Their small decks forced the British to rely for air superiority on a handful of Harriers, an aircraft neither designed nor equipped for such a role. British ship designs also proved flawed in that damage control systems were inadequate and some of the ships lacked armored cables. Initially only two ships in the invasion fleet carried modern missiles (Seawolf) for defense against low-level attacks.

Combat revealed the biggest British problem to be the lack of early warning aircraft. Although the British brilliantly and rapidly improvised to make good other serious deficiencies (such as adapting the land-based Harrier GR-3 to operate off aircraft carriers, expanding air-to-air refueling capabilities, mating the Sidewinder to the Harrier, and installing ECM aboard the Vulcan), this one glaring gap remained. And the inadequacy of early warning proved costly to the British. In short, the British entered the conflict ill prepared.[34]

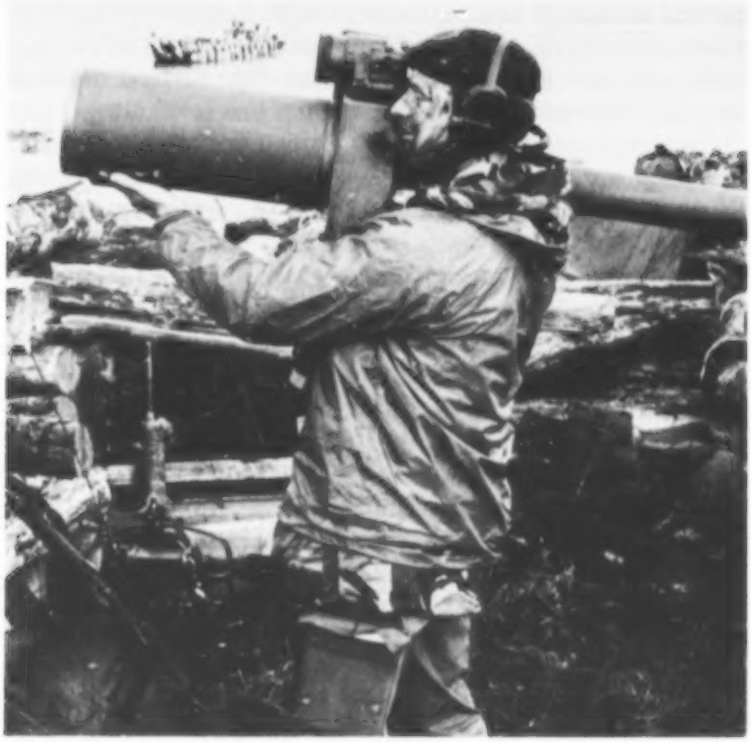
The British claimed the destruction of 72 aircraft in the air, not an unreasonable number when compared with the Argentine admission of 36 pilots killed in the campaign on 505 sorties. The Harriers downed 20 aircraft, small arms as many as six, naval 4.5-inch guns one, and 45 fell to various surface-to-air missiles.[35]

As usual, these numbers are probably overstated. Three recent books based on Argentine documents and interviews put total Argentine air losses between 50 and 55. Although these authors boost the Harriers' credits up to 21 to 26 of the air-to-air kills, they downgrade the surface-based weapons to 20 kills with an additional two to three attributed to Argentine ground fire.[36]

Although the British credit the Blowpipe with destroying nine Argentine aircraft, these authors say the true number is from two to four. The troops who carried the 47-pound Blowpipe through the difficult Falklands terrain criticized its weight (fig. 81).* The Blowpipe, like the SA-7 and American Redeye and Stinger (fig. 82), is operated by one man; but unlike the heat-seeking Soviet and American devices,

---

*Understandable criticism under the circumstances, but it did give the troops some protection against Argentine aircraft.

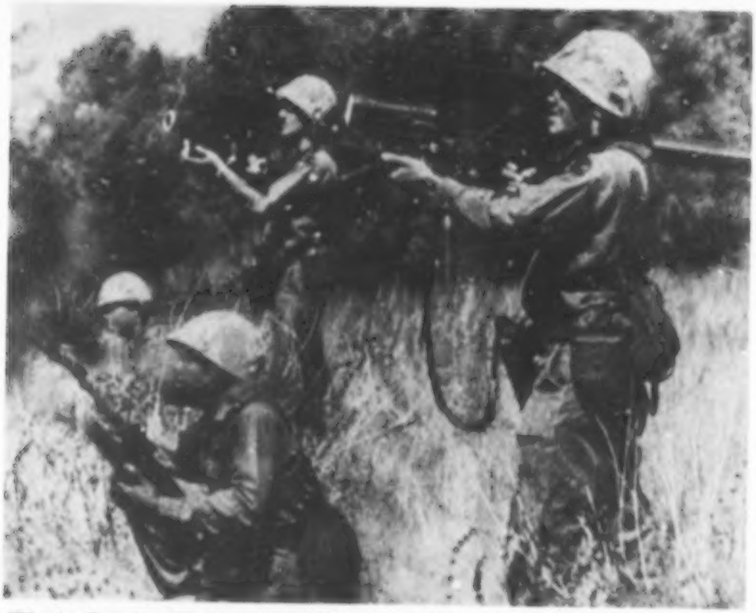


*(Photo Credit: Imperial War Museum)*

**Figure 81. Blowpipe launcher ashore on the Falkland Islands.**

Blowpipe is optically guided. Its record proved it could do the job, both ashore and afloat. One detachment aboard a Royal Fleet auxiliary fired six missiles and claimed three aircraft destroyed. The Argentines also used the Blowpipe and claimed one Harrier and two helicopters with it. In addition the British used the lighter weight Stinger but fired only four missiles for one kill. (However, there is some controversy about that particular credit.)[37]

The British initially credited the Rapier (fig. 83), the other ground-based SAM employed by the British, with 13



(Photo Credit: US Army Air Defense Artillery Museum)

Figure 82. Stinger.

kills, and later raised its kill ratio to 20. Just as the Roland kills are hotly disputed by the British, so are the Rapier kills by those who have seen Argentine documents and talked to Argentine pilots. (Perhaps this argument has more to do with future sales of these weapons than history.) The authors using Argentine sources put the Rapier credits at one to three. While the British stated that the campaign validates the weapon, the question of the actual kills cast some doubt on these assertions. Although the Army unit (T Battery) fired only with optical tracking, 40 percent of its kills were in the tail-chase mode. The missile's unique hittile (direct hitting missile) system (contact, not proximity fuzed) worked well, as British gunners often had to fire over their own men and ships (figs. 84 and 85). Firing over

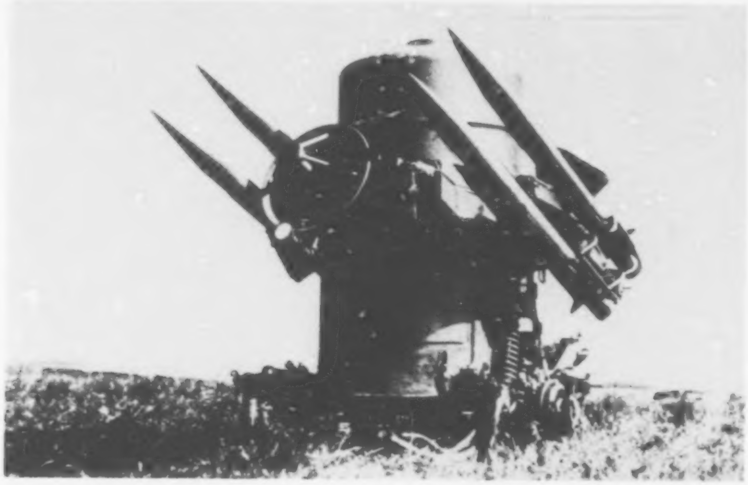
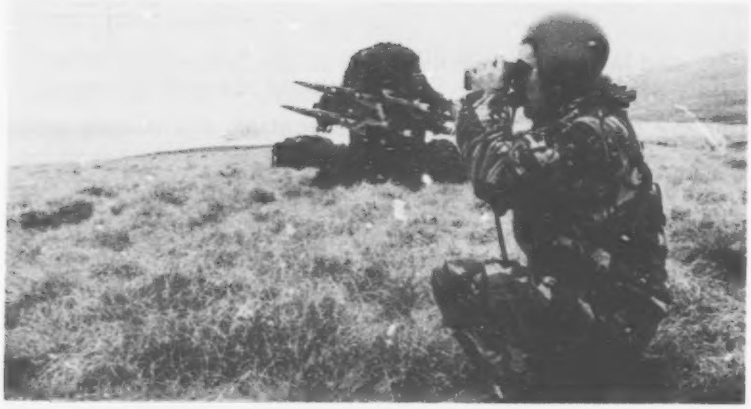
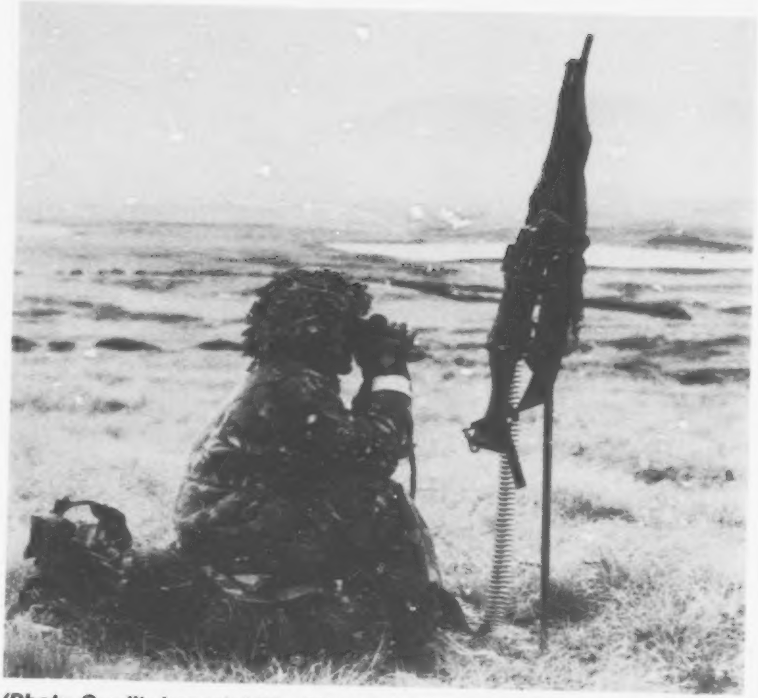


Figure 83. A Rapier surface-to-air antiaircraft missile system launcher.



*(Photo Credit: Imperial War Museum)*

Figure 84. Rapier system under a camouflage net.

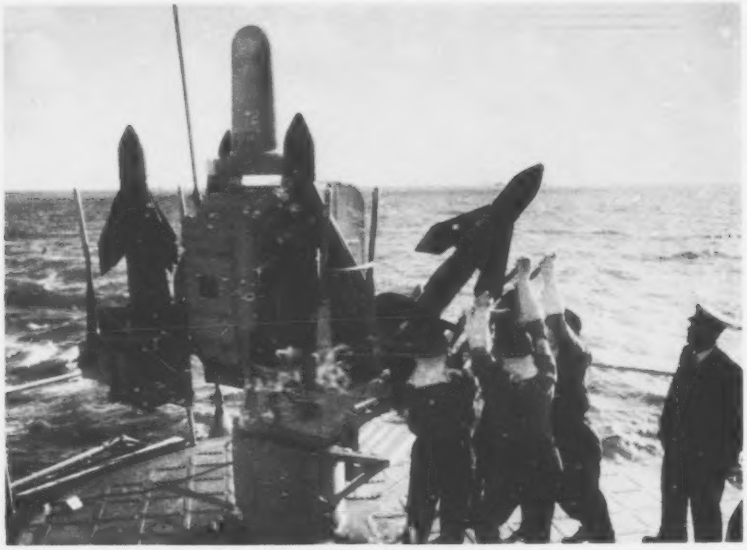


*(Photo Credit: Imperial War Museum)*

**Figure 85. 7.62-mm GPMG deployed ashore on the Falklands.**

friendly forces also highlighted another feature of the device, manual control (it is not a fire-and-forget weapon), which proved useful because the operator could pull the missile off a target if it flew behind friendly forces.[38]

The British naval air defense concept consisted of Harriers as air cover, destroyers armed with Sea Dart missiles as long-range defenses, and a close-in air defense of ships armed with guns and other missiles (figs. 86, 87, and 88). The British claim that Royal Navy SAMs downed a total of 21 aircraft. The large Seaslug missile (fig. 89), which entered service in 1962, received no credits. The two-stage Sea Dart destroyed five to eight aircraft, but more impor-

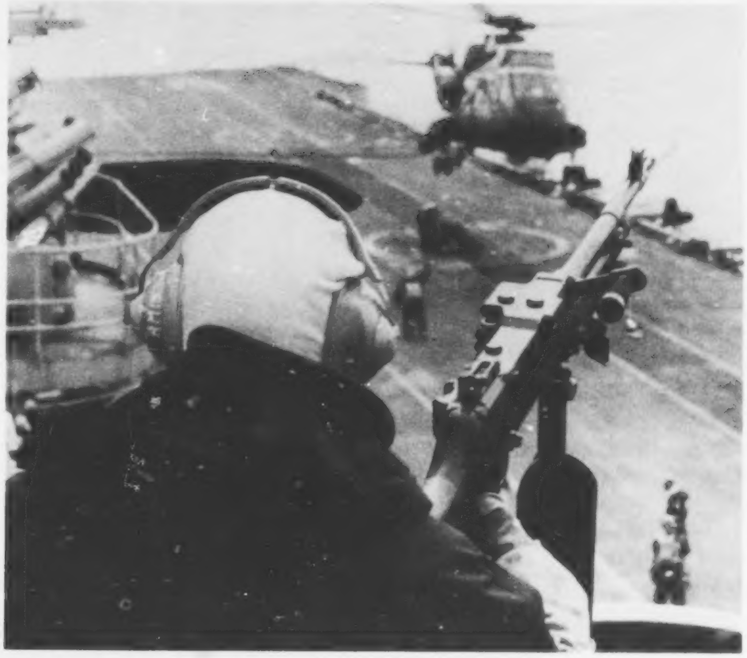


*(Photo Credit: Imperial War Museum)*

**Figure 86. Some British ships were also armed with surface-to-air missiles. Seacat being loaded during a training exercise.**

tant, forced Argentine aircraft into low-level tactics. However, it could handle only one target at a time, as was dramatically demonstrated when four A-4s attacked the HMS *Coventry*. The destroyer's Sea Darts destroyed the first two Argentine aircraft, but the third scored a direct hit which sank the ship (fig. 90). According to the manufacturer, obsolescent radar and computers hampered the missile. In addition, rougher seas than what the missile was designed to operate over degraded the system's performance against low-flying aircraft.[39]

The small, short-range Seacat began development in 1958 and is in service with a number of countries. Although British sources credit it with eight kills, other sources put this figure at one. The other short-range missile system was the more advanced Seawolf. Although clearly a better sys-

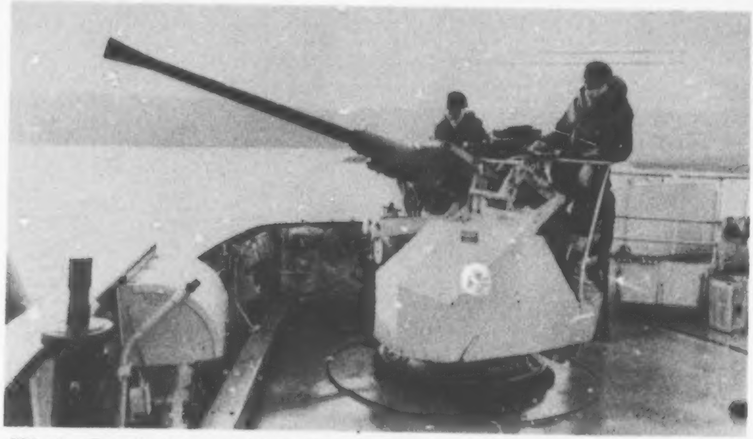


***(Photo Credit: Imperial War Museum)***

**Figure 87. The British used a variety of antiaircraft weapons during the Falklands campaign. These included rifle-caliber weapons such as this 7.62-mm GPMG mounted on HMS *Hermes*.**

tem than the Seacat, which it was designed to replace, there were just too few available, on only two ships. (Argentine duds hit both.) Nevertheless, this SAM received credit for downing three to five aircraft and at least one air-to-surface missile.[40]

Regardless of the dispute over claims, the Royal Navy's defenses proved inadequate: the Argentine Air Force came close to driving off the British fleet. Clearly, the Argentines came off better in the air-sea battle in terms of resources expended. Each British ship cost tens if not hundreds of millions of dollars; the HMS *Sheffield*, for example, cost



*(Photo Credit: Imperial War Museum)*

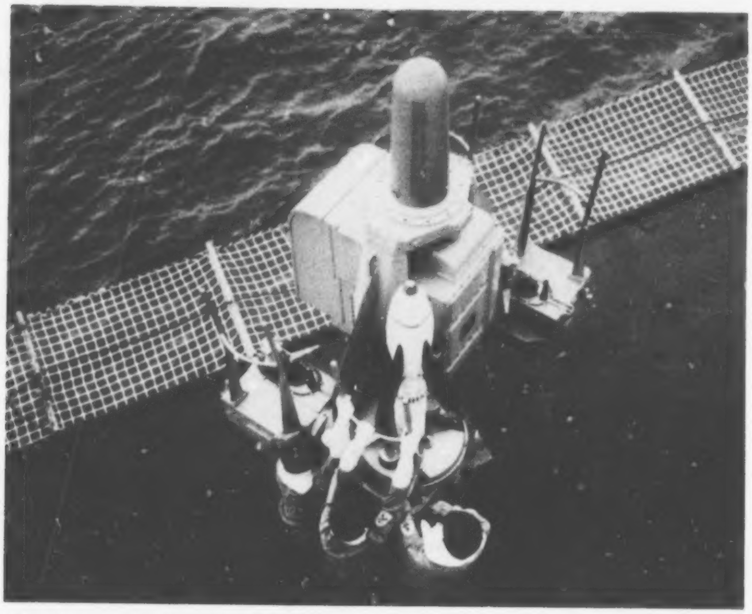
**Figure 88. The Bofors aircraft gun also served in the Falklands. 40-mm L/60 Bofors on board either HMS *Fearless* or HMS *Intrepid* during the Falkland War.**

$225 million. Argentine Exocets and aircraft cost far less, on the order of $200,000 for the missiles, and perhaps $5 million for a modern jet fighter.[41] But the British did win the war and did achieve their national objective.

## Ongoing and Recent Aspects

Since the dramatic actions in 1986, there have been no major air operations. Three other aspects should be mentioned, however, before closing out this study: the Iran-Iraq War, the invasion of Grenada, and guerrilla use of shoulder-fired SAMs.

Another recent and ongoing war (as of 1988) is the conflict between two third world countries, Iran and Iraq. Both have considerable quantities of relatively modern aircraft and air defense equipment: the Iranians with American aircraft and British and American missiles (Hawk, Rapier, and



*(Photo Credit: Imperial War Museum)*

**Figure 89. Seaslug.**

Tigercat); and the Iraqis with Soviet equipment, including 70 SAM batteries (SA-2, SA-3, and a few SA-6s). Reportedly, both sides lost about 150 aircraft by the end of 1981, most of the combat losses to ground weapons but apparently not through the efficiency of the enemy's air or ground defenses. Neither side has proved able to make good use of modern technology because of problems with parts, maintenance, and training. In addition, the main objective of both air forces seems to be to avoid attrition and defeat and to deter attacks. The lessons of this conflict therefore may be that modern equipment does not automatically make modern forces, and that air forces without access to secure support and resupply may adopt a defensive strategy to preserve their limited forces.[42]

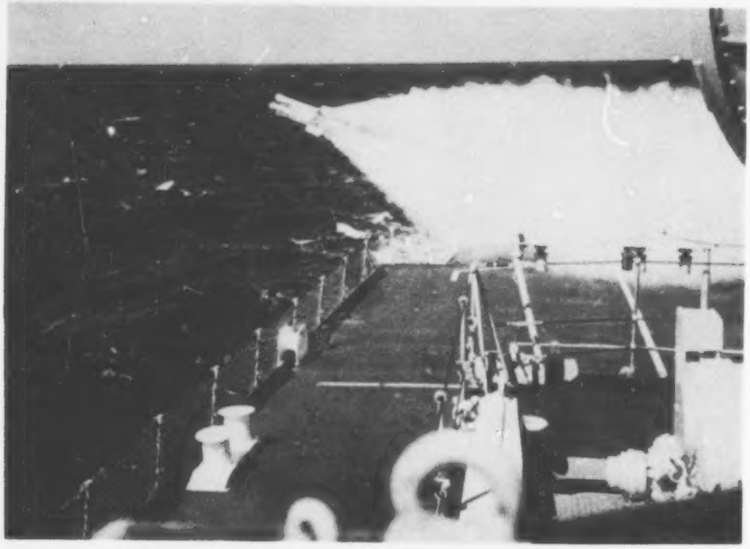


Figure 90. Sea Dart launch during peacetime.

The 1984 Grenada invasion will probably best be remembered for its nonmilitary aspects; nevertheless, air power played a significant role in the short, one-sided operation. The United States faced neither hostile aircraft nor any antiaircraft weapon greater than 23 mm—only small arms and 24 ZSU-23 guns, and these lacked radar guidance. Despite this imbalance, the defenders downed four helicopters (a fifth was destroyed after colliding with a damaged copter) and severely damaged at least four others. The loss of so many machines against such minor resistance here and in the 1975 *Mayaguez* incident, during which eight of nine helicopters that hit the beach were disabled, surfaces the question of helicopter survival in combat operations.[43]

Finally, in recent years guerrilla groups have claimed success against aircraft (fig. 91). Although it is difficult to separate guerrilla claims from their propaganda, a number of aircraft have gone down in antiguerrilla operations in Angola, Chad, Nicaragua, and the Sudan. Whether they were

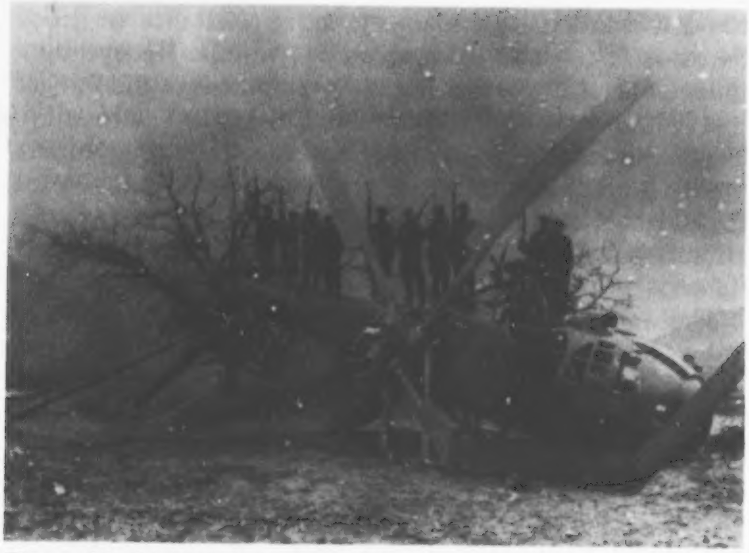


**Figure 91. Afghanistan rebels with downed Soviet helicopter in 1979. Uses of American and British shoulder-fired missiles beginning in 1986 changed the tide of the war.**

victims of SAMs, small arms, operational problems, or propaganda pens, remains to be seen. In any case, the acquisition of shoulder-launched SAMs gives the guerrillas, or the terrorists, a potent antiaircraft weapon.[44]

Particularly effective is the American built Stinger. Airmen, Americans in Vietnam and Soviets in Afghanistan, quickly found countermeasures to the first generation SA-7 and Redeye missile. Both missiles are limited by lack of electronic identification capability and three performance factors: They are strictly tail and chase (revenge) weapons, they are decoyed by flares, and they are restricted in maneuverability. The second-generation Stinger is a different story. It is a foot longer than the four-foot Redeye and weighs an additional 16 pounds. More important, the Stinger has improved performance in all four areas. In addition to having an electronic IFF capability, the Stinger has a forward firing capability, more resistance to decoy flares, is faster, and outranges the two-mile Redeye by a mile. General Dynamics began development of the Stinger in 1971, and it became operational in 1981. The missile's biggest success has been in Afghanistan. In fact its impact in that conflict prompted one reporter to write that: "What the longbow was to English yeomen . . . the Stinger antiaircraft missile is to today's American-backed guerrilla fighters."[45]

The war in Afghanistan clearly shows how missile technology has given the guerrillas a valuable weapon. The Soviets, while bogged down on the ground and largely confined to the cities and fortified positions, made effective and growing use of both fixed-wing and rotary-wing aircraft against sparse rebel antiaircraft defenses including SA-7 missiles. Therefore, in March 1986, the American and British agreed to ship Stingers and Blowpipe SAMs to the Afghanistan guerrillas.

The American Stingers were initially criticized for their weight and complexity, but after a month in which 11 were fired without a miss, they quickly showed their effectiveness. In October the guerrillas reportedly downed two helicopters and one fighter and in November 11 helicopters and one MiG-23. These losses forced the Soviets to fly higher and to operate at farther distances from their targets, and restrict, if not abandon, their gunship strikes, markedly reducing their military effectiveness. In February 1987 Air Force Chief of Staff Larry D. Welch testified that "somewhere between 150 and 300 Stingers have absolutely driven the Russian Air Force out of the skies in Afghanistan."[46] The rebels claimed to have downed as many as 15 to 20 Soviet helicopters a month and by the summer of 1987 may have downed one aircraft a day. During the fall 1987 offensive, the government reportedly lost 17 helicopters, an An-22 transport, and four MiG-21s to the Stingers.

The Stinger's impact goes beyond the aircraft losses. A Western journal reports that 20 Afghanistan pilots refused to fly against rebel positions defended by the American-built missiles. The Communists acknowledge the weapon's effectiveness and how it changed the conflict. The leader of the Afghanistan Communist party confirmed this defensive blow when he spoke of the siege of Khost, a city about 100 miles south of Kabul. He admitted that US and British SAMs had halted Communist daytime air supply of the city. Thus, the Communists have been forced to concede the countryside to the rebels, concentrate their forces in Kabul and other major cities, and make numerous moves toward withdrawal from the conflict. In this confrontation the American-built missile is playing a major role.[47]

## Summary

Any war is difficult to evaluate, but small wars are especially tricky. Because the amount of equipment used is usually small, and for the most part less than the most modern, it is difficult to extrapolate the findings into more general and future uses. When these wars are fought by other countries, the problems of interpretation increase. Nevertheless, it is the only laboratory the soldier has, and he must make the most of it.

The 1973 Arab-Israeli War presented many surprises, from its origin to the way it was fought. The Arabs did not follow the conventional wisdom but instead attacked a country having a superior military without having first gained air superiority. Initially, the Arabs used their air forces sparingly and advanced under a dense and lethal umbrella of SAMs and guns. This air defense proved effective and inflicted heavy losses on the Israeli Air Force. Arab missiles and guns sorely tested the IAF; but the Israelis changed their tactics, adopted new equipment, persisted, and won. However, Arab air defenses did not permit the Israelis to fight the air and ground war as they had done in 1967 and as they would have liked. As a result of this war, some commentators spoke of the demise of the tank and aircraft, victims of the modern missile. The defense seemed to be supreme.

But the wars of 1982 seemingly offered different lessons. The IAF won a small but striking victory against Syrian aircraft and SAMs. This came about through the use of coordinated efforts of all arms and especially through the use of high-technology equipment such as ARMs, remotely piloted vehicles (RPVs), and electronics aircraft.

The implications of the war in the Falklands appear less clear. It might be thought of as the converse of Vietnam; that is, a relatively sophisticated but small British force pitted against a larger but less-modern Argentine one. The Argentines used mostly old aircraft and old bombs, without ECM protection at the limits of their range. Not surprisingly, the British, with small numbers of aircraft and SAMs, imposed heavy losses on these aircraft and aircrews. But the Argentines did penetrate the defenses and did inflict much damage to the more costly British fleet. Nevertheless, the British won the war.

If these wars showed anything, they showed the potential of high technology. At the same time, they indicated that numbers and weapons handling are extremely important to the final outcome. High-technology weapons demand high-quality personnel.

## NOTES

1. Moshe Dayan, *Diary of the Sinai Campaign* (New York: Schocken Books, Inc., 1965), 177–78, 221; Chaim Herzog, *The Arab-Israeli Wars: War and Peace in the Middle East* (New York: Random House, 1982), 145; Trevor N. Dupuy, *Elusive Victory: The Arab-Israeli Wars, 1947–1974* (New York: Harper and Row, 1978), 212; Stephen Peltz, "Israeli Air Power," *Flying Review International*, December 1967, 1019.

2. Edward N. Luttwak and Daniel Horowitz, *The Israeli Army* (New York: Harper and Row, 1975), 229, 230; Nadav Safran, *From War to*

*War: The Arab-Israeli Confrontation, 1948–1967* (Indianapolis, Ind.: Bobbs-Merrill Co., Inc., 1969), 324, 325; Murray Rubenstein and Richard Goldman, *Shield of David* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1978), 100; Robert Jackson, *The Israeli Air Force Story* (London: Stacey, 1970), 218; Warren Wetmore, "Israeli Air Punch Major Factor in War," *Aviation Week*, 3 July 1967, 22; Edgar O'Ballance, *The Third Arab-Israeli War* (Hamden, Conn.: Archon Books, 1972), 67, 75, 82.

3. Jackson, *Israeli Air Force*, 153, 248; Wetmore, "Israeli Air Punch Major Factor in War," 22; James Hansen, "The Development of Soviet Tactical Air Defense," *International Defense Review*, May 1981, 532; "Off the Record," *Journal of Defense and Diplomacy*, January 1988, 63.

4. Jackson, *Israeli Air Force*, 233; Luttwak and Horowitz, *The Israeli Army*, 302, 321–23; Chaim Herzog, *The War of Atonement, October 1973* (Boston, Mass.: Little, Brown and Co., 1975), 8, 9, 232, 235–37, 253; the Insight Team of the Sunday *Times* (London), *The Yom Kippur War* (Garden City, N.Y.: Doubleday and Co., 1974), 33, 36; Lon O. Nordeen, *Air Warfare in the Missile Age* (Washington, D.C.: Smithsonian Institution Press, 1985), 134.

5. Hansen, "The Development of Soviet Tactical Air Defense," 533. Nordeen, *Air Warfare in the Missile Age*, 149–50; Herzog, *War of Atonement*, 256; Ronald Bergquist, *The Role of Airpower in the Iran-Iraq War* (Maxwell AFB, Ala.: Airpower Research Institute, September 1988).

6. Herzog, *The War of Atonement*, 256; Hansen, "The Development of Soviet Tactical Air Defense," 533; C. N. Barclay, "Lessons from the October War," *Army*, March 1974, 28; Charles Corddry, "The Yom Kippur War, 1973—Lessons New and Old," *National Defense*, May–June 1974, 508; Robert R. Ropelewski, "Setbacks Spur System to Counter Israel," *Aviation Week*, 7 July 1975, 15; Amnon Sella, "The Struggle for Air Supremacy: October 1973–December 1975," *RUSI Journal for Defense Studies*, December 1976, 33; Insight Team, *Yom Kippur*, 189.

7. Nordeen, *Air Warfare in the Missile Age*, 149; Luttwak and Horowitz, *The Israeli Army*, 348; Herbert J. Coleman, "Israeli Air Force Decisive in War," *Aviation Week*, 3 December 1973, 19; "U.S. Finds SA-6 to be Simple, Effective," *Aviation Week*, 3 December 1973, 22; Robert R. Ropelewski, "Egypt Assesses Lessons of October War," *Aviation Week*, 17 December 1973, 16; "SA-6–Arab Ace in the 20-Day War," *International Defense Review*, December 1973, 779–80; Robert Hotz, "The Shock of Technical Surprise," *Aviation Week*, 24 March 1975, 9.

8. Nordeen, *Air Warfare in the Missile Age*, 149; Ropelewski, "Egypt Assesses," 16; "Soviet Anti-Aircraft Gun Takes Toll," *Aviation Week*, 22 October 1973, 19.

9. Insight Team, *Yom Kippur*, 161, 184–85; Herzog, *The Arab-Israeli Wars*, 281, 346; Herzog, *The War of Atonement*, 87, 256; J. Viksne, "The Yom Kippur War in Retrospect," *Army Journal*, April 1976, pt. 1:41; "Israeli Aircraft, Arab SAMs in Key Battle," *Aviation Week*, 22 October 1973, 14; Historical Evaluation and Research Organization, "The Middle East War of October 1973 in Historical Perspective," study, February 1976, 145 [AUL-M42138-5]; Dupuy, *Elusive Victory*, 551; Bryce Walker, *Fighting Jets* (Alexandria, Va.: Time-Life Books, 1983), 149; Peter Borgart, "The Vulnerability of the Manned Airborne Weapon System, Part 3: Influence on Tactics and Strategy," *International Defense Review*, December 1977, 1066.

10. Nordeen, *Air Warfare in the Missile Age*, 165; Luttwak and Horowitz, *The Israeli Army*, 349; Coleman, "Israeli Air Force Decisive in War," 19; "SA-7 Avoids Homing on Flares," *Aviation Week*, 5 November 1973, 17; Robert R. Rodwell, "The Mid-East War: A Damned Close-Run Thing," *Air Force Magazine*, February 1974, 39; Hotz, "The Shock of Technical Surprise," 9.

11. Nordeen, *Air Warfare in the Missile Age*, 349, 351; Jeffrey Greenhunt, "Air War: Middle East," *Aerospace Historian*, March 1976, 22.

12. Rodwell, *The Mid-East War*, 39; Dupuy, *Elusive Victory*, 552; Nordeen, *Air Warfare in the Missile Age*, 156; Luttwak and Horowitz, *The Israeli Army*, 349; Insight Team, *Yom Kippur*, 187–88, 370; Coleman, "Israeli Air Force Decisive in War," 19; Bill Gunston et al., *War Planes: 1945–1976* (London: Salamander, 1976), 58; Walker, *Fighting Jets*, 149; Borgart, "Vulnerability, Part 3," 1064.

13. Insight Team, *Yom Kippur*, 204; Walker, *Fighting Jets*, 150; Coleman, "Israeli Air Force Decisive in War," 18.

14. One author states that the IAF destroyed 28 SAM sites and the Israeli Army 12 others. Herzog, *War of Atonement*, 242, 259; Insight Team, *Yom Kippur*, 338; Herzog, *Arab-Israeli Wars*, 285, 341; Rubenstein and Goldman, *Shield of David*, 127, 129.

15. Herzog, *Arab-Israeli Wars*, 346–47; Herzog, *War of Atonement*, 257; Luttwak and Horowitz, *The Israeli Army*, 347; Nordeen, *Air Warfare in the Missile Age*, 163–66; M. J. Armitage and R. A. Mason, *Air Power in the Nuclear Age*, 2d ed. (Urbana, Ill.: University of Illinois, 1985), 134; Roy M. Braybrook, "Is It Goodbye to Ground Attack?" *Air International*, May 1976, 234–44; Charles Wakebridge, "The Technological Gap in the Middle East," *National Defense*, May–June 1975, 461; "SA-6–Arab Ace," 779.

16. "Bekaa Valley Combat," *Flight International*, 16 October 1982,

1110; Herzog, *The War of Atonement*, 260; Insight Team, *Yom Kippur*, 315; Thomas Walczyk, "October War," *Strategy and Tactics*, March–April 1977, 10; Martin van Creveld, *The Washington Papers, Military Lessons of the Yom Kippur War: Historical Perspectives*, no. 24 (Beverly Hills/London: Sage Publications, 1975), 31; Peter Borgart, "Vulnerability, Part 3," 1064, 1066; Rubenstein and Goldman, *Shield of David*, 128; Herzog, *Arab-Israeli Wars*, 347; Ropelewski, "Egypt Assesses," 16.

17. Rubenstein and Goldman, *Shield of David*, 113; Dupuy, *Elusive Victory*, 592; Nordeen, *Air Warfare in the Missile Age*, 151; Herzog *Arab-Israeli Wars*, 266; Herzog, *War of Atonement*, 258; Lawrence Whetten and Michael Johnson, "Military Lessons of the Yom Kippur War," *World Today*, March 1974, 109.

18. Herzog, *The War of Atonement*, 260–61; Corddry, "The Yom Kippur War," 508; Historical Evaluation and Research Organization, "The Middle East War," appendix; Walczyk, "October War," 10; William Staudenmaier, "Learning from the Middle East War," *Air Defense Trends*, April–June 1975, 18; "Israeli Aircraft, Arab SAMs in Key Battle," 14; Rubenstein and Goldman, *Shield of David*, 128; Borgart, "Vulnerability, Part 3," 1066. A number of factors contribute to the discrepancy in losses. Besides the differences in the training, leadership, motivation, and doctrine of the opposing forces, two other factors stand out: Soviet equipment versus Western equipment, and the Arab lack of ECM equipment and Israel's use of it. Dupuy, *Elusive Victory*, 549; Coleman, "Israeli Air Force Decisive in War," 18; Nordeen, *Air Warfare in the Missile Age*, 162–63.

19. Van Creveld, "Military Lessons," 31, 32; Luttwak and Horowitz, *The Israeli Army*, 350, 351; Hansen, "The Development of Soviet Tactical Air Defense," 533; Historical Evaluation and Research Organization, "The Middle East War," 148, 177; Drew Middleton, "Missiles Blunt Thrust of Traditional Tank-Plane Team," *New York Times*, 17 October 1973, 19; John Finney, "New Missiles Are Enabling Infantry to Counter Planes and Tanks," *New York Times*, 2 November 1973, 19.

20. "Bekaa Valley Combat," 1110; William Haddad, "Divided Lebanon," *Current History*, January 1982, 35.

21. "Anti-Aircraft Defence Force: The PLO in Lebanon," *Born in Battle*, no. 27, 7, 32.

22. R. D. M. Furlong, "Israel Lashes Out," *Interavia*, August 1982, 1002, 1003; Clarence Robinson, Jr., "Surveillance Integration Pivotal in Israeli Successes," *Aviation Week*, 5 July 1982, 17; Edgar Ulsamer, "In Focus: TAC Air Feels the Squeeze," *Air Force Magazine*, October 1982, 23; Anthony Cordesman, "The Sixth Arab-Israeli Conflict,"

best copy available

*Armed Forces Journal International*, August 1982, 30. The IAF may have destroyed as many as 108 Syrian aircraft. "Syrian Resupply," *Aerospace Daily*, 15 November 1982, 74.

23. Furlong, "Israel Lashes Out," 1002, 1003; Robinson, "Surveillance Integration Pivotal in Israeli Successes," 17; Ulsamer, "In Focus: TAC Air Feels the Squeeze," 23; Cordesman, "The Sixth Arab-Israeli Conflict," 30; "Bekaa Valley Combat," 1110; Drew Middleton, "Soviet Arms Come in Second in Lebanon," *New York Times*, 19 September 1982, 2E; "Israeli Defense Forces in the Lebanon War," *Born in Battle*, no. 30, 22, 45–47; "The Syrians in Lebanon," no. 27, 12, 28, 31–33; "SA-9 Firings Seen Part of Attempt to Probe Israeli Capabilities," *Aerospace Daily*, 8 November 1982, 45.

24. Eugene Kozicharow, "Navy Blames Aircraft Loss on Soviet Sensor Change," *Aviation Week*, 12 December 1983, 25–26; Richard Halloran, "Navy, Stung by Criticism, Defends Cost of Bombing Raid in Lebanon," *New York Times*, 7 December 1983, 1, 19; Thomas Friedman, "US Ships Attack Syrian Positions in Beirut Region," *New York Times*, 14 December 1983, 1.

25. "US Demonstrates Advanced Weapons Technology in Libya," *Aviation Week*, 21 April 1986, 19; Fred Hiatt, "Jet Believed Lost, 5 Sites Damaged in Raid on Libya," *Washington Post*, 16 April 1986, A25; Anthony Cordesman, "After the Raid," *Armed Forces*, August 1986, 359.

26. Cordesman, "After the Raid," 358, 360.

27. Ibid., 355–60; "US Airpower Hits Back," *Defence Update/73*, 1986, 27–32; Hiatt, "Jet Believed Lost," A25; "US Demonstrates Advanced Weapons Technology in Libya," 20, 21; David M. North, "Air Force, Navy Brief Congress on Lessons from Libya Strikes," *Aviation Week*, 2 June 1986, 63; Judith Miller, "Malta Says Libya Got Tip on Raid," *New York Times*, 6 August 1983, 1, 8.

28. John Fricker, *Battle for Pakistan: The Air War of 1965* (London: Allan, 1979), 122, 124, 183, 184. Slightly different claims can be found in Nordeen, *Air Warfare in the Missile Age*, 113.

29. John Fricker, "Post-Mortem of an Air War," *Air Enthusiast*, May 1972, 230, 232; Nordeen, *Air Warfare in the Missile Age*, 103–4; Borgart, "Vulnerability, Part 3," 1066; Pushpindar Chopra, "Journal of an Air War," *Air Enthusiast*, April 1972, 177–83, 206.

30. Great Britain, Ministry of Defence, *The Falklands Campaign: The Lessons* (London: Her Majesty's Stationery Office, 1982), annex B [AUL-MU37324-18]; Dov Zakheim, "The South Atlantic: Evaluating the Lessons" (Paper delivered at Southern Methodist University (SMU) Conference on The Three Wars of 1982: Lessons to be Learned, Dallas, Tex., 15 April 1983), 29.

31. Jeffrey Ethell and Alfred Price, *Air War South Atlantic* (New York: Macmillan Publishing Co., Inc., 1983), 146.

32. Ibid., 180–81; David Brown, "Countermeasures Aided British Fleet," *Aviation Week*, 19 July 1982, 18; "British Government on Performance of Roland, Rapier in Falklands," *Aerospace Daily*, 27 October 1982, 309; "British SAMs Credited with Most Kills in Falklands Conflict," *Aerospace Daily*, 9 August 1982, 211; Sunday *Times* (London) Insight Team, *War in the Falklands* (Cambridge, Mass.: Harper and Row Publishers, 1982), 201; Great Britain, Ministry of Defence, *The Falklands Campaign*, 19, annex C; Derek Wood and Mark Hewish, "The Falklands Conflict, Part 1: The Air War," *International Defense Review* 8 (1982): 978, 980; Brian Moore, "The Falklands War: The Air Defense Role," *Air Defense Artillery*, Winter 1983, 19; "Blowpipe Draws Commendation for Falklands Performance," *Aerospace Daily*, 12 August 1982, 239; David Griffiths, "Layered Air Defense Keyed British Falklands Victory," *Defense Week*, 30 August 1982, 13. The French claimed that nine Roland missiles downed four Harriers and damaged another, a claim fiercely disputed by the British. Interestingly, the British had attempted to sell their Rapier missile to the Argentines. "Euromissile on Performance of Roland in Falklands, Middle East," *Aerospace Daily*, 23 September 1982, 126; "Exocet, Roland Combat Performance Rated High," *Aviation Week*, 1 November 1982, 26; Anthony Cordesman, "The Falklands: The Air War and Missile Conflict," *Armed Forces Journal International*, September 1982, 40.

33. Brad Roberts, "The Military Implications of the Falklands/ Malvinas Island Conflict," report no. 82-140F, Congressional Research Service, Library of Congress, August 1982, 15 [AUL-M42953-1-U#82-140f]; Cordesman, "The Falklands," 33, 35; Steward Menaul, "The Falklands Campaign: A War of Yesterday?" *Strategic Review*, Fall 1982, 87, 88; Wood and Hewish, "Falklands Conflict, Part 1," 978; Ezio Bonsignore, "Hard Lessons from the South Atlantic," *Military Technology*, June 1982, 32; John Guilmartin, Jr., "The South Atlantic War: Lessons and Analytical Guideposts, A Military Historian's Perspective," 17; SMU Conference, April 1983; Ethell and Price, *Air War*, 120–21, 183, 217–18; Jesus Romero Briasco and Salvador Mafe Huertas, *Falklands: Witness of Battles* (Valencia, Spain: Domenech, 1985), 172.

34. Guilmartin, "The South Atlantic War," 12; Ethell and Price, *Air War*, 179.

35. I have relied primarily on the official British reports for the statistics, Great Britain, Ministry of Defence, *Falklands Campaign*, annex B. Also see the figures, which vary at times from these numbers,

in Wood and Hewish, "Falklands Conflict, Part 1," 980; Moore, "The Falklands War," 21; Cordesman, "The Falklands," 32; Guilmartin, "The South Atlantic War," 17.

36. Ethell and Price, *Air War*, 207; Briasco and Huertas, *Falklands*, 165–68, 173: Rodney A. Burden et al., *Falklands: The Air War* (London: Arms and Armour, 1986), 33–147.

37. Derek Wood and Mark Hewish, "The Falklands Conflict, Part 2: Missile Operations," *International Defense Review*, September 1982, 1151, 1154; Moore, "The Falklands War," 20; Christopher Foss, "European Tactical Missile Systems," *Armor*, July–August 1975, 24; Ethell and Price, *Air War*, 196–208; Briasco and Huertas, *Falklands*, 165–69; Terry Gander, "Maintaining the Effectiveness of Blowpipe SAM," *Jane's Defence Review* 4, no. 2 (1983): 159.

38. Some accounts claim that Rapier's radar interfered with the Royal Navy's radar. After all, the British army did not expect to fight alongside destroyers on the plains of central Europe! Others state that the British sent the army unit to the Falklands without radar, in contrast to the RAF regiment that arrived later with Rapier and radar. Whatever the case, the initial unit that went ashore in the campaign, and the only one that saw action, fired optically guided missiles. "UK Planned to Use Shrike Missiles Against Argentine Radars," *Aerospace Daily*, 30 August 1982, 334; "Air Defense Missiles Limited Tactics of Argentine Aircraft," *Aviation Week*, 19 July 1982, 21; Great Britain, Ministry of Defence, *The Falklands Campaign*, 22; Wood and Hewish, "The Falklands Conflict, Part 2," 1153; Moore, "The Falklands War," 19; Ethell and Price, *Air War*, 196–208; Briasco and Huertas, *Falklands*, 165–69; Jacques du Boucher, "Missiles in the Falklands," *African Defence*, October 1983, 60.

39. John Laffin, *Fight for the Falklands* (New York: St. Martin's Press, 1982), 92, 93; Great Britain, Ministry of Defence, *The Falklands Campaign*, 9, annex B; Wood and Hewish, "The Falklands Conflict, Part 2," 1151, 1154; Ethell and Price, *Air War*, 196–208; Briasco and Huertas, *Falklands*, 165–69.

40. Cordesman, "The Falklands," 38; Great Britain, Ministry of Defence, *The Falklands Campaign*, annex B; Insight Team, *War in the Falklands*, 216; Ethell and Price, *Air War*, 196–208; Briasco and Huertas, *Falklands*, 165–69; Roger Villar, "The Sea Wolf Story—GW S25 to VM40," *Jane's Defence Review* 2, no. 1 (1981): 75.

41. Cordesman, "The Falklands," 34; Alistair Horne, "A British Historian's Meditations: Lessons of the Falklands," *National Review*, 23 July 1982, 888.

42. Anthony Cordesman, "Lessons of the Iran-Iraq War: Part II, Tactics, Technology, and Training," *Armed Forces Journal Interna-*

*tional*, June 1982, 70, 78, 79; "The Iranian Air Force at War," *Born in Battle*, no. 24, 13; "The Iraq-Iran War," *Defence Update*, no. 44 (1984): 43–44; Nordeen, *Air Warfare in the Missile Age*, 185–88; *Role of Air Power in the Iran-Iraq War*.

43. Stephen Harding, *Air War Grenada* (Missoula, Mont.: Pictorial Histories, 1984), 9, 33, 36, 51; stated in Thomas D. Des Brisay, "The Mayaguez Incident," in *Air War—Vietnam* (Indianapolis, Ind.: Bobbs-Merrill Co., Inc., 1978), 326.

44. Jean de Galard, "French Jaguar Shot Down in Chad," *Jane's Defence Weekly* 1, no. 4 (4 February 1984): 142; Charles Mohr, "Contras Say They Fear a Long War," *New York Times*, 16 June 1986, 8; Pico Iyer, "Sudan: Stranded Amid the Gunfire," *Time*, 1 September 1986, 34; William Claiborne, "S. African Military Says Intervention in Angola Staved Off Rebel Defeat," *Washington Post*, 13 November 1987, A28.

45. John H. Cushman, Jr., "The Stinger Missile: Helping to Change the Course of a War," *New York Times*, 17 January 1988, E2; Ray Barnes, ed., *The U.S. War Machine* (New York: Crown Publishers, 1978), 234–35; Maurice Robertson, "Stinger: Proven Plane Killer," *International Combat Arms*, July 1985; General Dynamics, *The World's Missile Systems* (Pomona, Calif.: General Dynamics, 1982).

46. "Soviets Press Countermeasures to Stinger Missile," *Aerospace Daily*, 6 August 1987, 205; "Disjointed Rebels Join Forces as They Oust Their Enemy," *Insight*, 25 January 1988, 21; Anthony Cordesman, "The Afghan Chronology: Another Brutal Year of Conflict," *Armed Forces*, April 1987, 156–60.

47. Cordesman, "Afghan Chronology," 158–60; Cushman, E2; Rone Tempest, "Afghan Rebel Rockets Jar Government Assembly," *Washington Post*, 30 November 1987, A24; John Kifner, "Moscow Is Seen at Turning Point in Its Intervention in Afghanistan," *New York Times*, 29 November 1987, 1; Peter Youngsband, "Grappling for the Advantage When Talk Replaces Gunfire," *Insight*, 7 December 1987, 43; Robert Schultheis, "The *Mujahedin* Press Hard," *Time*, 18 May 1987, 51; Steven R. Weisman, "U.S. in Crossfire of Border War," *New York Times*, 17 May 1987, E3.

## CHAPTER 5

# SUMMARY, TRENDS, AND CONCLUSIONS

Ground-based air defenses have been a problem for airmen from the onset of manned flight. Although seldom able to stop air power, air defenses have made air operations both costly and dangerous. For just as aircraft have become more capable so have air defenses. This extended offensive versus defensive battle shows no sign of lessening, in fact, every sign points to it becoming more complex and costly as it continues.

## Summary

Airmen have had to contend with ground-based air defense since it downed its first aircraft in 1912. In every war except World War I, more American aircraft have been lost to antiaircraft artillery than to fighters; nevertheless, air-to-air combat has dominated the public's mind. The military has suffered a similarly mistaken and romantic attitude regarding the relative merits of hostile flak and fighters.

Probably this attitude denigrating AAA and the defense (the idea that the bomber would always get through) peaked in the 1930s and 1940s. During the early years of World War II, the offense did have the advantage and flak was ineffective. But aviation advanced modestly between 1935 and 1945. (For example, the B-17, which first flew in 1935, was still frontline equipment in 1945, as were such fighters as the Me-109 and Spitfire, which first flew in 1935 and 1936.) These aircraft, and others like them, are more representative of air combat in World War II than the better performing, and perhaps better remembered, B-29s and Me-262s.

In contrast, the defense made great strides during the war. Flak grew from an ineffective nuisance weapon into a potent force by 1944. Although AAA could not stop determined airmen, it could inflict heavy losses on the flyers, disrupt accuracy, and in general make air operations much more expensive. The notable antiaircraft successes, such as British guns in the V-1 campaign, German flak defense of the oil targets, and American defense of the Remagen Bridge, clearly support this point. Compared to aircraft, flak proved inexpensive and very cost-effective.

The two major technical advances responsible for this improvement and success were radar and proximity fuzes. Radar stripped the cloak of surprise and invisibility from aircraft. It provided detection and warning of attacking aircraft, allowed control of defensive fighters, and permitted more accurate all-weather, day/night firing of the guns. Other devices increased the lethality of flak, none more so than proximity fuzes.

As a result, airmen learned that AAA constituted a dangerous and powerful force. World War II also proved that low-level operations in the face of flak were costly because guns were increasingly effective at lower altitudes. Strafing fighters were particularly vulnerable. Another air defense difficulty involved correctly identifying friend and foe: ideally, not engaging the former and always engaging the latter. Experience showed numerous instances, however, of friends downed by "friendly" fire and gunners letting foes slip by.

To counter ground fire, the airmen adopted tactics that would be used again and again in subsequent air wars. Besides avoiding flak areas, the flyers used surprise, the sun, the terrain, and one-pass attacks. They also employed ECM, specifically chaff and jammers. Finally, the airmen attacked their tormentors; but direct action seldom proved effective, although usually expensive. The trade-off of cheap guns versus valuable aircraft made direct attack a high-risk and low-return proposition.

So, during the course of World War II, the balance between air offense and air defense tilted toward the defense. But events in the last stages of the war obscured these facts. The introduction of jets radically improved aircraft performance, just as the atomic bomb enormously expanded firepower. Therefore, both the public and military saw the offensive as again supreme.

But the combatants used only the jet, not the atomic bomb, in America's next war, Korea, which was different from World War II and the wars that the prophets and theorists had forecast. "Peasant hordes" stalemated the strongest nation in the world on the periphery of Asia. With the exception of the MiG-15, the Communists used only limited numbers of obsolete equipment to thwart and impose considerable losses on the Allied airmen. Air power was not decisive in the war. At the same time, the war reemphasized many of the basic AAA lessons from World War II—the lethality of flak, the danger of low-altitude operations, and the usefulness of antiflak countermeasures.

In many respects, the Vietnam War repeated the same pattern. Again, American airmen were unprepared for the reality of combat and especially their chief opponent, AAA. Again, the lessons of World War II and Korea had to be relearned. Again, the air power of the strongest nation in the world proved indecisive against Asian peasants armed with simple weapons.

The one new air defense weapon introduced into combat in Vietnam was the surface-to-air missile (SAM). Although these missiles claimed relatively few aircraft, they made air operations more difficult and expensive. American tactics and equipment overcame the SAMs, but the missiles forced the airmen to increase the number of support aircraft and operate at low altitudes where AAA proved deadly.

American airmen learned to cope with the ground-based defenses. They used electronic countermeasures (ECM), antiradiation missiles (ARMs), and standoff weapons that showed the impact of technology on modern combat. Linebacker II clearly demonstrated that modest numbers (compared to World War II or current Soviet inventories) of second-rate air defense equipment could not stop large-scale air efforts by a major power but could inflict both a burden and loss on the attacker.

Shortly after the Americans closed out their involvement in the Vietnam War, air operations in the Middle East seemed to indicate the predominance of the defense. For unlike the 1967 Arab-Israeli War in which the Israeli Air Force was overwhelmingly supreme and triumphant, the 1973 war indicated the renewed power of the defense.

The Arabs violated the basic rules of war by attacking a country with superior military forces while lacking air superiority. They advanced under a dense umbrella of SAMs and guns, and they downed many Israeli Air Force aircraft. Although the Israelis won the war, they suffered heavy aircraft losses and their air force was unable to influence operations as it had in 1967. Ground-based air defenses seemed to have regained the edge.

Operations in 1982 between the Arabs and Israelis cast doubt on these findings. In a short and sharp action, the Israeli Air Force won an air battle against Syrian MiGs and SAMs, a battle about as lopsided as their 1967 victory.

A few months earlier, on the other side of the world, the lessons of another conflict were less clear. In the Falklands, a small force from a Western power defeated a larger force from a third world country. However, the Argentine Air Force battered the Royal Navy despite the restrictions of range, old aircraft, old bombs, and lack of ECM. Although the British air defense imposed heavy losses on the attackers, the Argentines did get through to severely punish the defenders.

## Trends (Speculations)

What does all this mean? What are the lessons of the past and what do they tell us about the future? Just as in weather forecasting, it is probably a safe bet to expect more of the same (and also to expect some unpleasant surprises). It seems that we can expect to see more capable air defense systems fielded in the future. The capabilities of missiles on the drawing boards indicate that they will become harder to jam, more difficult to evade, and more effective against many more attackers. The key to advancements in air defense appears to be in the area of electronics. The devices will become more complex as they become more capable. Sensors will improve, and the almost total reliance on radar will end. Different types of sensors will be tied together and will give more data more quickly to the air defenders. All of this will be much more expensive in terms of dollars and trained manpower.

A second expectation is that effective air defense weapons will spread in numbers and geography. We can expect most countries to equip their forces with missiles, and sometimes we will see our own weapons used against us. In addition, man-portable SAMs will give antiaircraft protection to guerrilla groups and will give terrorists a potent weapon.

Although costs of all weapons will dramatically increase throughout the coming years, air defense will retain its cost advantage over similarly modern aircraft. AAA always has been cheaper than aircraft, and there is no indication that this relative cost imbalance will change.

Future military conflicts may be decided not so much on the combat performance of weapons (that is their probability of kill, time of flight, lethal radius, launch envelope, ECM, and electronic counter-countermeasures—ECCM) but on other factors. These will include nontechnical factors—numbers of weapons in the field and in the supply depots as well as maintainability and reliability—and human factors—training, adaptability, and motivation.

What are the big payoff areas in the future? Improved ECM will be useful but increasingly difficult because of the introduction of multisensors on a large scale and ECCM. Most of all, the airmen need capable and versatile standoff weapons: the attacker must get away from the defenders. These weapons offer the advantages of increased accuracy (thereby requiring fewer sorties) and increased reach (permitting less risk to the airmen). The air defenders also need more ECM and ECCM. The big area of opportunity is in the field of multiple sensors. Both the friendly air defenders and their airmen partners would greatly benefit from the introduction of effective identification equipment. Until the problem of rapidly and accurately sorting out friends from foes is solved, the effectiveness of both the offense and defense will be greatly reduced. In short, the area that needs to be exploited is electronics. Advances in civilian technology indicate that much can be expected from electronics: less expensive, smaller, and more capable equipment. Therefore, the future seems to belong to those who can best use, not just field, modern, high-cost, high technology in combat. This will decide the outcome of wars and the balance between the offense and defense.

## Conclusions

US Air Force assumptions about future conflicts have proved to be in error. Since 1945 the Air Force has geared itself for air-to-air combat and a nuclear exchange with a major power. Although this is certainly America's most serious challenge, it has turned out to be the least likely one. For the reality of war has proved to be far different. Since World War II the US Air Force has fought in two wars against minor powers, used conventional weapons, and found its chief opposition to be ground-based air defense weapons. Not only did the nature of war prove different from the one anticipated, but the technology took a turn away from the offense to favor the defense. The big contributor to this shift in the balance between the offense and defense was the emergence of effective surface-to-air missiles.

The airmen never appreciated the impact of ground-based air defense systems until it was too late. The US Air Force used ECM, direct action, and tactics to nullify the defensive threat but, in so doing and in relearning old lessons, suffered heavy losses. What should be emphasized to all American military personnel, especially all airmen, is that since World War I and especially since early 1944, US airmen have lost more aircraft in combat to ground-based air defense systems than to hostile aircraft. There is no indication that the future will be any different.

Prospects seem to favor the air defender. Proliferation of potent ground-based air defense systems throughout the world will continue and intensify. In addition, these weapons will become more effective as the electronics revolution makes them smarter. Aircraft weapons will also improve but, relative to aircraft, air defense systems will become cheaper. In brief, then, the airman will face a greater quantitative and qualitative threat in the future.

American airmen should realize that increased capabilities of ground-based air defenses challenge them in two important ways. The first and most obvious way is to make their job more difficult and dangerous, whether it be in a major conflict with a major foe or in a minor conflict with a minor foe. The other aspect is the impact of this air offense/defense balance on friendly powers, who will undoubtedly request US assistance for their air force problems.

This study indicates the potential pitfalls of air defense systems and possible solutions to counter these systems from past and recent experience. For clearly, ground-based air defense weapons are a vital issue to American airmen of today and tomorrow. If our airmen are to be successful, they must meet and master the challenge of these systems.

# *INDEX*

Page numbers in bold indicate illustrations.

- A-1: 116
- A-4: **110**, 138, 151, 160
- A-6: **100**, 123, 148-49
- A-7: 134, 148
- A-20: **55, 56**
- A-37: 116
- AAA. See antiaircraft artillery
- AC-130: 116
- Accuracy degraded
  - German Air Force
    - Battle of Britain: 5
  - Great Britain, 1941: 43
  - United States Army Air Forces
    - 1944–45: 43
    - Korean War: 74
    - Leuna: 31
- Acoustical devices: 2
- Afghan War: **165**, 165-67
  - Aircraft losses, Soviet: 166
- AGM-45. See Shrike
- AGM-78. See Standard
- Air Corps Tactical School: 58, 60
- Aircraft
  - Argentina
    - Pucará: 151, 154
  - France
    - Mirage: 145, 151
    - Super Etendard: 151
  - Germany
    - FW 190: 23
    - Ju 88: 22
    - Me 109: 177
    - Me 163: 37
    - Me 262: 178
  - Great Britain
    - Canberra: 151, **152**
    - Gazelle: 154
    - Harrier: **153**, 153-55, 159, 173
    - Hunter: 150
    - Scout: 154
    - Spitfire: 23, 49, 177
    - Typhoon: 46, 49
    - Vampire: 150
    - Vulcan: 151, **152**, 153, 155
  - Israel
    - Arava transport: 147
  - Soviet Union
    - An-12: 150
    - An-22: 166
    - Mi-8: 145
    - MiG: 125
    - MiG-15: 179
    - MiG-19: 130
    - MiG-21: 85, 128, 135, 150, 166
    - MiG-23: 166
    - Su-7: 146n
  - United States
    - A-1: 116
    - A-4: **110**, 138, 151, 160
    - A-6: **100**, 123, 148-49
    - A-7: 134, 148
    - A-20: **55, 56**
    - A-37: 116
    - AC-130: 116
    - B-17: 34, 44, **48**, 54, 177
    - B-24: 29, 34, **47**, 54
    - B-25: 50
    - B-26: **77**, 77
    - B-29: 54, **56**, 178
    - B-52: 101, 116, **120**, **121**, 120-25, 133-35
    - B-66: 108
    - Boeing 707: 147
    - C-47: 23, **47**
    - C-119: 78, **79**
    - C-123: 97, **98**
    - C-130: 150
    - CH-21: **97**
    - CH-53: **113**, 147
    - Choctaw: **114**

        - EA-6A: 109
        - EA-6B: 118, **119**, 149
        - EB-66: **109**, 108-9, 116, 122
        - EC-135: 147
        - EF-10B: 108
        - EF-111: 149
        - EKA-3B: 108
        - F-4: **103**, 103, 116-17, 125, 134
        - F4U: 75, 78
        - F9F: 75
        - F-51: **75**, 75, 76n
        - F-80: **76**, 76
        - F-86: 78, 150
        - F-100F: 109
        - F-104: 150
        - F-105: 100, **101**, 109, **111**, 118, 128
        - F-111: 100, 120, 125, 134
        - FB-111: 149
        - H-34: **114**
        - P-38: 29
        - P-47: 23, 44-45, 50, 76n
        - P-51: 23, 49-50, 76n
        - RB-57F: 150
        - RF-4C: **104**
        - T-6: 80, **81**
        - U-2: 105, 130
- Aircraft losses
    - Allied to German antiaircraft artillery: 42, 45n
    - United States
        - Korean War: 74-76, 75n
        - Vietnam War: 97, 112, 118, 125, 135
        - World War II vs. Japan: 54n
- Aircraft technology
    - Interwar: 3
- Air-to-air combat ratio: kills/losses
    - Korean War: 129
    - Vietnam War: 129
    - World War II: 129
- ALE-38: 118
- ALQ-51: 111
- ALQ-71: 111
- An-12: 150
- An-22: 166
- AN/ALE-38: **118**
- Antiaircraft artillery
    - Cost effectiveness: 58
    - Countermeasures, World War II: 43-46
    - Direct attack
        - Vietnam: 109, 111, 118
        - World War II: 44-46
    - Impact during World War II: 58
- Antiaircraft gun, improvisioned, World War I: **3**
- Antiradiation missiles: 118, 127, 147, 168, 179
        - Shrike: **110**, 110-11, **111**, 123, 125, 144, 153
        - Standard: 110-11, 123, **124**, 125
        - Wolf: 147
- Antwerp, Belgium: 19-21, 50
- Ap Bac: 96
- Applied Physics Laboratory: 87
- AQM-34V: **118**
- Arab-Israeli War. See Middle East War
- Arava transports: 147
- Argentina
    - Aircraft
        - Pucará: 151, 154
    - Falkland War: 151-62, 168, 173, 180
- ARM. See antiradiation missiles
- Arnheim, Holland: 57
- Ascension Island: 154
- Asch, Belgium: 22-23
- Avranches: 22

- B-17: 34, 44, **48**, 54, 177
- B-24: 29, 34, **47**, 54
- B-25: 50
- B-26: **77**, 77
- B-29: 54, **56**, 178
- B-52: 101, 116, **120**, **121**, 120-25, 133-35
    - Linebacker II
        - B-52D and B-52G: 121, 133
        - Electronic countermeasures: 121-22
        - Losses: 120-21
- B-66: 108

Baldwin, Stanley (quote): 5
Barrel liners, removable: 2
Battle of Britain: 5
Battle of the Bulge: 22
Beeson, Duane W.: 69
Bekaa Valley, Lebanon: 146-47
Bell Laboratories: 82-83
Bendix Talos: 87
Bloodhound: 89
Blowpipe: 151, 153-56, **156**, 166
  Falkland War claims: 154-56
Boeing: 89
Boeing 707: 147
Bomarc: 89, **90**, **91**
Breech mechanisms, automatic: 2
British Bomber Command: 50
British women gunners: 6, **7**
Bumblebee project: 87

C-47: 23, 47
C-119: 78, **79**
C-123: 97, **98**
C-130: 150
Canberra: 151, **152**
Cape Canaveral, Florida: **91**
Cape Gloucester, Bismarck Archipelago assault: 50
Carpet: 43
CBU. See cluster bomb unit
CH-21: 97
CH-53: **113**, 147
Chaff: 43, **44**, 117-18, 122-23, 143, 147, 178
Cherbourg, France: 46
Choctaw: **114**
Churchill, Winston (quote): 4
Claims
  Argentina: 153-54, 173
  Falkland War: **152**-57, 159-61, 173
  Germany
    1940–41: 27
    Leuna: 31
    Ploesti: 29-31
    Vienna: 32
  Great Britain
    1940–41: 5-6
    1942–43: 10
    Battle of Britain: 5
    Falkland War: 153-57, 159-61, 173
    Malta: 8-9
    Tobruk: 7-8
    V-1 campaign: 17-19
  Indian-Pakistani Wars: 150-51
  Japan: 54
  Middle East War
    1956: 137
    1967: 138
    1967–70: 138
    1967–73: 138-39
    1973: 145
    1982: 146
  Soviet Union
    World War II: 67
  United States Army
    3 December 1944: 22
    Avranches: 22
    Battle of the Bulge: 22
    Normandy: 21
    Remagen: 23
    World War I: 1-2
    World War II: 23
  United States Navy
    5-inch: 52
    20-mm: 51
    40-mm: 52
    Talos: 136
    Terrier: 136
  World War I: 1-2
  World War II: 5-6, 8-10, 17-19, 21-23, 29-32, 51-52, 54, 67
Cluster bomb unit: 111, 118
Cologne: 29
Convair: 87
Crotale: 149

D-day: 49
Defense-offense resource ratio, World War I: 1
Dien Bien Phu
  Aircraft losses, French: 96
  Guns, number of Communist: 96

    Impact of Vietminh antiaircraft artillery: 95-96
Director, gun
  Great Britain: **7**
Doolittle, James: 50
Douglas: 83
Douhet, Giulio: 4, 58

EA-6A: 109
EA-6B: 118, **119**, 149
EB-66: **109**, 108-9, 116, 122
EC-135: 147
ECM. See electronic countermeasures
EF-10B: 108
EF-111: 149
EKA-3B: 108
Electronic countermeasures: 33, 43, 54, 58, 147, 149, 168, 171, 178-83
  Carpet: 43
  Chaff: 43, **44**, 117-18, 122-23, 143, 178
  Effectiveness, World War II: 44
  Falkland War: 153-55, 168, 180
  Libyan raid: 149
  Middle East War: 143, 147, 171
  Pods: 111, 139, 147
  Vietnam War: 101, 107-8, 112, 117-18, 121-23
  World War II: 43-44
Enzian: 37-38, **39**
Exocet: 154, 162

F-4: **103**, 103, 116-17, 125, 134
F4U: 75, 78
F9F: 75
F-51: **75**, 75, 76n
F-80: **76**, 76
F-86: 78, 150
F-100F: 109
F-104: 150
F-105: 100, **101**, 109, **111**, 111, 118, 128
  Poorly designed: 128
F-111: 100, 120, 125, 134
Falkland War: 151-62, 168, 173, 174, 180
  Aircraft losses
    Argentina: 154-55
    Great Britain: 153-54
  Argentine Air Force, impact of: 154
  Claims
    Argentina: 153-54, 156, 173
    Great Britain: 155-57, 159-61
  Dud bombs: 154
  Electronic countermeasures: 153-55, 168, 180
  Great Britain
    Claims: 154-57, 159-61
    Improvisations: 155
FB-111: 149
Finucane, Brendan: 69
Foehn: 37
Fractricide: 46-47, 49-51, 59
  Battle of Britain: 5
  Cape Gloucester, Bismarck Archipelago, December 1943: 50
  D-day, June 1944: 49
  German Air Force, 1 January 1945: 22, 59
  Korean War: 78
  Middle East War: 138, 145
  Pacific theater, December 1943–June 1944: 50
  Sicily incidents, July 1943: 47, 49, 59
  United States Marine Corps: 51
France
  Aircraft
    Mirage: 145, 151
    Super Etendard: 151
  Dien Bien Phu: 95-96
  Surface-to-air missiles
    Crotale: 149
    MATRA R422-B: 90
    PARCA: 90
    Roland: 151, 154, 157, 173
  World War I: 1
Fuzes

  - Increased effectiveness, Germany: 33
  - Proximity: 17, 58, 178
    - Falkland War: 157
    - Germany: 34, 40-41
    - Korean War: 79
    - Ratio, increased effectiveness, V-1 campaign: 17
    - United States Navy: 52
- Fuze setters
  - Automatic, Great Britain: 9
  - Continuous: 3
- FW 190: 23

- Gabreski, Francis S.: 69
- GAPA: 89
- Gazelle: 154
- General Electric: 89
- Germany
  - Air attack, 1 January 1945: 22, 57, 59
  - Aircraft
    - FW 190: 23
    - Ju 88: 22
    - Me 109: 177
    - Me 163: 37
    - Me 262: 178
  - Air defense effectiveness, kills/sorties: 53
  - Antiaircraft artillery
    - Assigned to Luftwaffe, 1934: 24
    - Banned: 23
    - Personnel: 41
    - Problems, 1944–45: 41
    - Strait of Messina, August 1943: 27-29
  - Claims
    - 1940–41: 27
    - Guns: 42
    - Leuna: 31
    - Ploesti: 29-31
    - Vienna: 32
  - Fuzes: 33
    - Proximity: 34, 40-41
  - Guns
    - 7.7-cm: **2**
    - 8.8 cm flak – 18/36/37: 24n, 25
    - 20-mm: **33, 34, 35**
    - 40-mm Bofors: **35**
    - 50-mm: **36**
    - 88-mm: 3, 24, **25**, **26**, **27**, 30
    - 105-mm: 25-26, 30
    - 128-mm: 26, **28**, 30, **36**
    - Railroad-mounted: 26, **34**, **36**
    - Romanian 75-mm: 30
    - Soviet 76.5-mm: 30
  - Guns, mix of
    - Ploesti: 30
  - Guns, number of
    - 1939: 24
    - Hamburg: 32
    - Leuna: 31
    - Munich: 32
    - Ploesti: 29-30, **36**
    - Politz: 31
    - Vienna: 32
  - Radar: **31**, 43
    - Gun-laying: 33
  - Rockets: 34, 37, 58
  - Spanish Civil War: 24
  - Surface-to-air missiles
    - Enzian: 37-38, **39**
    - Foehn: 37
    - Rheintochter: 38-39, **40**
    - Roland: 151, 154, 157, 173
    - Schmetterling: 39, **41**
    - Taifun: 37, **38**
    - Wasserfall: 39-41, **42**, 104
  - Units
    - JG 11: 22
  - V-1. See V-1
  - V-2: 19, 39, 41
  - World War I: 1
  - World War II losses: 23
- Goering, Hermann: 37
- Great Britain
  - Air attack
    - Cologne: 29
    - Leuna: 31
    - Ploesti: 29
  - Aircraft
    - Canberra: 151, **152**
    - Gazelle: 154

    - Harrier: **153**, 153-55, 159, 173
    - Hunter: 150
    - Scout: 154
    - Spitfire: 23, 49, 177
    - Typhoon: 46, 49
    - Vampire: 150
    - Vulcan: 151, **152**, 153, 155
  - Antiaircraft artillery personnel: 6-7
    - Home Guard: 6
    - Numbers: 6-7
    - Territorial forces: 6
    - Women: 6, **7**
  - Battle of Britain: 5
  - Casualties caused by Germany: 19
  - Claims
    - 1940–41: 5-6
    - 1942–43: 10
    - Battle of Britain: **5**
    - Falkland War: 153-57, 159-61, 173
    - Malta: 8-9
    - Tobruk: 7-8
    - V-1 campaign: 17-19
  - Falkland Islands war: 153-61, 173
  - Guns
    - 3-inch: 4
    - 3.7-inch: 4-5, **15**, 19, 24n
    - 7.62-mm GPMG: **159, 161**
    - 20-mm: 10, 17
    - 20-mm Bredas: 8
    - 40-mm Bofors: 8, **9**, 10, 17, **162**
    - Two-pound: 52
  - Guns, mix of
    - 1943: 10
    - Battle of Britain: 5
  - Guns, number of
    - 1938-40: 5
    - 1943: 10
    - World War I: 1
  - Gun technology: 9
  - Radar: 4, 6, 13
  - Rockets: 7n, **8**, 13, 17
  - Surface-to-air missiles
    - Bloodhound: 89
    - Blowpipe: 151, 153 - 56, **156**, 166
    - Rapier: 153, 156-57, **158**, 162, 173-74
    - Seacat: 151, 153, **160**, 160-61
    - Sea Dart: 151, 153, 159-60, **164**
    - Seaslug: 89, 153, 159, **163**
    - Seawolf: 153, 155, 160-61
    - Thunderbird: 89
    - Tigercat: 163
  - Units
    - 41st Squadron: 22
    - 130th Squadron: 22
    - 350th Squadron: 22
    - 610th Squadron: 22
    - British Bomber Command: 50
    - T Battery: 157
    - V-1. See V-1
    - World War I: 1
- Grenada invasion: 164
  - Helicopter losses: 164
  - ZSU-23: 164
- Grooved projectiles: 33
- Gulf of Tonkin incident: 97
- Guns
  - Germany
    - 7.7-cm: **2**
    - 8.8 cm flak – 18/36/37: 24n, 25
    - 20-mm: **33, 34, 35**
    - 40-mm Bofors: **35**
    - 50-mm: **36**
    - 88-mm: 3, 24, **25**, **26**, **27**, 30
    - 105-mm: 25-26, 30
    - 128-mm: 26, **28**, 30, **36**
    - Railroad-mounted: 26, **34**, **36**
    - Romanian 75-mm: 30
    - Soviet 76.5-mm: 30
  - Great Britain
    - 3-inch: 4
    - 3.7-inch: 4-5, **15**, 19, 24n
    - 7.62-mm GPMG: **159, 161**
    - 20-mm: 10, 17
    - 20-mm Bredas: 8
    - 40-mm Bofors: 8, **9**, 10, 17, **162**
    - Two-pound: 52
  - Soviet Union
    - 76.5-mm: 30

    85-mm Model 1939: 74
    85-mm Model 1944: 74
    ZSU-23: 164
    ZSU-23-4: 135, 140-42, **142**
  United States
    .50-caliber: 23, 51, 72
    1.1-inch: 51
    3-inch: 2, **4**, 4
    5-inch/38-caliber: 52
    20-mm: 51
    37-mm: 23, 52
    40-mm: 23, 51-52, 72
    75-mm Sky Sweeper: 72, 72n, **73**
    90-mm: 4, 17, 19, **21**, 23, 24n
    Vulcan: 146n
Gun technology
  Great Britain 1943: 9
  Interwar: 2-3

H-34: **114**
Haiphong, North Vietnam: **124**
Hamburg: 43
  Defenses of: 32
Hanson, Robert: 69
Harrier: **153**, 153-55, 159, 173
Hawk: 72, **85**, 85-86, 138-39, 145, 162
Helicopter losses
  Grenada: 164
  *Mayaguez* incident: 164
  Middle East War, 1977: 145
  Vietnam War: 113-15, 131
Hill, Roderic: 11, 14, 16
Hitler, Adolph: 11, 24, 37
HMS *Coventry*: 160
HMS *Fearless*: **162**
HMS *Hermes*: **161**
HMS *Intrepid*: **162**
HMS *Sheffield*: 161
Hunter: 150

Identification, friend or foe: 49, 165
Identification problem. See fratricide
IFF. See identification, friend or foe

Indian-Pakistani War, 1965: 150
  Aircraft losses: 150
  Claims: 150
Indian-Pakistani War, 1971: 150-51
  Aircraft losses: 151
  Claims: 151
Iran-Iraq War: 162-63
  Aircraft losses: 163
  Surface-air-missile units: 163
Iron Hand: 109, 111, 118
Israel (See also Middle East wars)
  Aircraft
    Arava transport: 147
Italy
  Antiaircraft artillery, World War I: 1

Japan
  Air defense effectiveness, kills/sorties: 53
  Antiaircraft artillery: 53-57
  Claims, World War II: 54
  Guns
    75-mm type 4: 53
    75-mm type 88: 53
    88-mm: 53
    120-mm: 53
    150-mm: 53
  Guns, mix of: 53
  Guns, numbers of: 53
Johns Hopkins University: 87
Johnson, Lyndon B.: 112
Ju 88: 22

Kissinger, Henry: 119
Korean War: 72-81, 129, 179
  Aircraft losses
    Jet compared with propeller: 75-76
    United States: 74-75, 75n
  Air tactics: 77-79
  Antiaircraft artillery
    Countermeasures: 78-80
  Lessons: 81
  United States Air Force
    Aircraft losses: 75n
    Air tactics: 77-80

- United States Marine Corps
  - Aircraft losses: 54n, 75, 75n, 78
  - Air tactics: 78
- United States Navy
  - Aircraft losses: 54n, 75, 75n
  - Air tactics: 77-78

- Lam Son 719: 113
- Lebanon strike, 1983
  - Aircraft losses: 148
  - Air tactics: 148
- Leuna: 31
- Libya strike
  - Air tactics: 149
  - Antiradiation missiles: 149
  - Electronic countermeasures: 149
  - Surface-to-air missiles, number of: 149
- Liège, Belgium: 20
- Linebacker I: 116-19
- Linebacker II: 107, 119-27, 133, 135
- LORAN: 117, 124
- Low-level operations: 22-23, 29, 57

- Malta: 8-9
- Market-Garden: 44-45
- MATRA R422-B: 90
- *Mayaguez* incident: 164
- McDonnell: 87
- McNamara, Robert: 103
- McNaughton, John T.: 103
- Me 109: 177
- Me 163: 37
- Me 262: 178
- Meyer, John: 23
- Mi-8: 145
- Middle East War, 1956: 137
- Middle East War, 1967: 138, 180
- Middle East War, 1967–70: 138
- Middle East War 1967–73: 139
- Middle East War, 1973: 135, 139-46, 167, 180
  - Aircraft losses
    - Israel, initial: 142-43, 145
  - Air defenses
    - Impact of: 145
  - Air tactics
    - Israel: 143-44
  - Canal crossing: 144
  - Claims: 145
  - Electronic countermeasures: 143, 171
  - Fratricide: 138, 145
  - Guns
    - ZSU-23-4: 135, 140-42, **142**
  - Helicopter losses: 145
    - Loss discrepancy: 171
  - Surface-to-air missiles
    - Direct attack of: 144
    - SA-6: 135, 140-41, 143-45
    - Units: 140
- Middle East War, 1982: 146-47, 168, 180
  - Aircraft losses: 146
  - Air tactics: 147
  - Claims: 146
  - Electronic countermeasures: 147
  - Guns
    - Vulcan: 146n
  - Surface-to-air missiles: 146
- MiG: 125
- MiG-15: 179
- MiG-19: 130
- MiG-21: 85, 128, 135, 150, 166
- MiG-23: 166
- Mirage: 145, 151
- Mitchell, William "Billy": 4
- Munich, defenses of: 32

- Nancy, France: 50
- Na San, Vietnam: 95
- NEGAT: 78
- New Year's Day, 1945 German air attack: 22
- Night kills
  - Battle of Britain: 5
- Nike Ajax: 82-83, **83**, 105
- Nike Hercules: 83, **84**, 85
- Nixon, Richard M.: 112, 119
- Normandy: 21
- North Korea (See also Korean War)
  - Guns, number of: 74
  - Rockets: 74

North Vietnam (See also Vietnam War)
  Air defenses
    Underestimated: 101-2
  Antiaircraft artillery guns: **98**

Oil Campaign 1944: 57
Operation Bolo: 102

P-38: 29
P-47: 23, 44-45, 50, 76n
P-51: 23, 49-50, 76n
PARCA: 90
Patton, George: 50
Pearl Harbor: 50n
Peenemünde: 18
Philco-Ford: 86
Pile, Frederick A.: 14
Pile mattress: **14**, 14, **15**
Pile portable platforms. See Pile mattress
Ploesti: 29-31, **30**, **32**, **36**, 57
  Claims: 29
Politz: 31
Powers, Francis G.: 130
Preddy, George E., Jr.: 69
Predictors, electric: 9
Propellants, flashless: 9
Proximity fuzes. See fuzes, proximity
Pucará: 151, 154

Quesada, Elwood "Pete" (quote): 4

Radar: 58, 178
  Falkland War: 153, 160, 174
  Germany: **31**, 33, 43
  Great Britain: 4, 6, 13
  Libya: 149
  Middle East War, 1983: 147
  United States: 17
Radar homing and warning: 109
Rapier: 153, 156-57, **158**, 162, 173-74
  Falkland War claims: 156-57
Raytheon: 85
RB-57F: 150
Redeye: **86**, 155, 165-66
Regulus II: 89
Remagen: 23, 57, 178
RF-4C: **104**
Rheintochter: 38-39, **40**
Ridgway, Matthew B.: 47
Rockets
  Germany: 34, 37, 58
  Great Britain: 7n, **8**, 13, 17
  North Korea: 74
Roland: 151, 154, 157, 173
  Falkland War claims: 173
Rolling Thunder: 99-112
RSD 58: 90
Rules of engagement
  9th Tactical Air Command, 1944: 50
  Great Britain, V-1 campaign: 13-17

Sabot devices: 34, 34n
SAC. See Strategic Air Command
SAM. See surface-to-air missiles
Schmetterling: 39, **41**
Scout: 154
Seacat: 151, 153, **160**, 160-61
  Falkland War claims: 160
Sea Dart: 151, 153, 159-60, **164**
  Falkland War claims: 159
Seaslug: 89, 153, 159, **163**
Seawolf: 153, 155, 160-61
  Falkland War claims: 160-61
Shrike: **110**, 110-11, **111**, 123, 125, 144, 153
Sicily: 47, 49, 59
Smart bombs: 117
Soviet Union
  Aircraft
    An-12: 150
    An-22: 166
    Mi-8: 145
    MiG: 125
    MiG-15: 179
    MiG-19: 130
    MiG-21: 85, 128, 135, 150, 166
    MiG-23: 166
    Su-7: 146n
  Claims

    - World War II: 67
  - Guns
    - 76.5-mm: 30
    - 85-mm Model 1939: 74
    - 85-mm Model 1944: 74
    - ZSU-23: 164
    - ZSU-23-4: 135, 140-42, **142**
  - Surface-to-air missiles
    - SA-1: 104
    - SA-2: 103-5, **104**, **105**, **106**, 107-8, 110, 112, 116, 122, 130, 138-41, 149-51, 163
    - SA-3: 135, 139-41, 149, 163
    - SA-5: 149
    - SA-6: 135, **141**, 140-46, 149, 163
    - SA-7: **115**, 115-16, 140-41, 143, 145, 148-49, 155, 165-66
    - SA-8: 147, 149
    - SA-9: 140, 147-49, **148**
- Spaatz, Carl: 50
- Spanish Civil War: 24
- Spitfire: 23, 49, 177
- Squeeze bore: 34, 34n
- Standard: 110-11, 123, **124**, 125
- Stinger: 153, **157**
  - Afghan War: 165-66
  - Falkland War: 155-57
- Strait of Messina: 27-29
- Strategic Air Command: 101, 122
- Su-7: 146n
- Super Etendard: 151
- SUPPRESS: 79
- Surface-to-air missiles
  - Countermeasures
    - Air tactics: 107-12, 122-23, 125-26, 143-44, 147
    - Antiradiation missiles: **110**, 110-11, **111**, 118, 123, **124**, 125, 127, 144, 147, 153, 168, 179
  - France
    - Crotale: 149
    - MATRA R422-B: 90
    - PARCA: 90
    - Roland: 151, 154, 157, 173
  - Germany
    - Enzian: 37-38, **39**
    - Foehn: 37
    - Rheintochter: 38-39, **40**
    - Roland: 151, 154, 157, 173
    - Schmetterling: 39, **41**
    - Taifun: 37, **38**
    - Wasserfall: 39-41, **42**, 104
  - Great Britain
    - Bloodhound: 89
    - Blowpipe: 151, 153-56, **156**, 166
    - Rapier: 153, 156-57, **158**, 162, 173-74
    - Seacat: 151, 153, **160**, 160-61
    - Sea Dart: 151, 153, 159-60, **164**
    - Seaslug: 89, 153, 159, **163**
    - Seawolf: 153, 155, 160-61
    - Thunderbird: 89
    - Tigercat: 163
  - Soviet Union
    - SA-1: 104
    - SA-2: 103-5, **104**, **105**, **106**, 107-8, 110, 112, 116, 122, 130, 138-41, 149-51, 163
    - SA-3: 135, 139-41, 149, 163
    - SA-5: 149
    - SA-6: 135, **141**, 140-46, 149, 163
    - SA-7: **115**, 115-16, 140-41, 143, 145, 148-49, 155, 165-66
    - SA-8: 147, 149
    - SA-9: 140, 147-49, **148**
  - Switzerland
    - RSD 58: 90
  - United States
    - Bomarc: 89, **90**, **91**
    - Bumblebee project: 87
    - GAPA: 89
    - Hawk: 72, **85**, 85-86, 138-39, 145, 162
    - Nike Ajax: 82-83, **83**, 105
    - Nike Hercules: 83, **84**, 85
    - Redeye: **86**, 155, 165-66
    - Stinger: 153, 155-56, **157**, 165-66
    - Talos: 87, **88**, 136
    - Tartar: 87, **88**

    Terrier: 87, 136
    Thumper: 89
    Wizard: 89
Switzerland
  Surface-to-air missiles
    RSD 58: 90

T-6: 80, **81**
Tactical Air Command: 101
Taifun: 37, **38**
Talos: 87, **88**, 136
Tartar: 87, **88**
Terrier: 87, 136
Tet offensive: 112
Thanh Hoa Bridge: 117
Thumper: 89
Thunderbird: 89
Tigercat: 163
Tobruk: 7-8
  Guns
    Claims: 8
    Mix of: 8
    Number of: 8
Tokyo: 54
Tonkin incident. See Gulf of Tonkin incident
Trenchard, Hugh: 4
Tuck, Robert: 69
Turnhout: 45
Typhoon: 46, 49

U-2: 105, 130
United States Air Force
  Aircraft. See specific designation. See also aircraft, United States; Korean War; Vietnam War
  Aircraft losses
    Korean War: 75n
  Surface-to-air missiles
    Bomarc: 89, **90**, **91**
    GAPA: 89
  Units
    18th Fighter Bomber Wing: **75**
    315th Air Commando Wing: **98**
    355th Tactical Fighter Wing: **109**
    452d Bomb Wing: **77**
    Fifth Air Force: 76-78, 80
    Strategic Air Command: 101, 122
    Tactical Air Command: 101
United States Army
  Air Corps Tactical School: 58, 60
  Antiaircraft artillery
    Post-World War II. 72
    World War I: 1-2
  Claims
    3 December 1944: 22
    Avranches: 22
    Battle of the Bulge: 22
    Normandy: 21
    Remagen: 23
    World War I: 1-2
    World War II: 23
  Guns
    .50-caliber: 23, 72
    3-inch: 2, **4**, 4
    37-mm: 23
    40-mm: 23, 72
    75-mm Sky Sweeper: 72, 72n, **73**
    90-mm: 4, 17, 19, **21**, 23, 24n
    Vulcan: 146n
  Guns, mix of, Remagen: 23
  Guns, number of, Remagen: 23
  Ordnance Corps: 83
  Surface-to-air missiles
    Hawk: 72, **85**, 85-86, 138-39, 145, 162
    Nike Ajax: 82-83, **83**, 105
    Nike Hercules: 83, **84**, 85
    Redeye: **86**, 155, 165-66
    Stinger: 153, 155-56, **157**, 165-66
    Thumper: 89
    Wizard: 89
  Units
    62d Coast Artillery: **4**
    82d Airborne Division: 47
    Eighth Army: 80
    First Army: 21-23
    Third Army: 23
    Ninth Army: 23

IX Corps: 80
World War I: 1-2
United States Army Air Forces
Air attack
Leuna: 31
Ploesti: 29-31, **30**, **32**, **36**, 57
Vienna: 32
Aircraft. See specific designation. See also aircraft, United States
Aircraft losses
To German AAA: 42
To Japan: 54n
Air tactics: 58
Change of against Japan: 54
Leuna: 31
Ploesti: 29-31, **30**, **32**, **36**, 57
Units
Eighth Air Force: 43, 45
8th Fighter Command: 50
Ninth Air Force: 45-46
9th Tactical Air Command: 45, 50
Fifteenth Air Force: 32, 45
Twentieth Air Force: 54, 57
56th Fighter Group: 45
352d Fighter Group: 22-23
366th Fighter Group: 22
Mediterranean Air Force: 43
United States Strategic Air Forces in Europe: 45
United States Marine Corps
Aircraft losses
Japan: 54n
Korean War: 75n
Korean War: 74-75, 78
United States Navy
Aircraft. See specific designation. See also aircraft, United States
Aircraft losses
Japan: 54n
Korea: 75, 75n
Guns
.50-caliber: 51
1.1-inch: 51
5-inch/38-caliber: 52
20-mm: 51
37-mm: 52
40-mm: 51-52
Surface-to-air missiles
Bumblebee project: 87
Talos: 87, **88**, 136
Tartar: 87, **88**
Terrier: 87, 136
Vietnamese aircraft shot down: 136
University of Michigan: 89
USS *Boston*: 87
USS *Chicago*: 136
USS *Enterprise*: **100**
USS *Galveston*: 87, **88**
USS *Helena*: 52
USS *Long Beach*: 136
USS *McCormick*: **88**
USS *Sterett*: 136

V-1: 10, **11**, 66, 178
Bomber-launched: 18
Difficult target: 12
Long-range version: 18
Performance: 10
V-1 campaign: 10-21
Antwerp
Casualties: 21
Defenses of: **20**, 50
Guns, mix of: 19
Guns, number of: 19
V-1s launched against: 19
V-1s reaching: 20
Casualties inflicted by V-1s
Continent: 21
Great Britain: 19
Claims
Balloons: 18
Continental defenses: 19
Defenses: 17-19
Fighters: 18
Guns: 17-18
Continental campaign: 19-21
Great Britain
Balloons: 18
Casualties: 19
Claims

    Defenses: 17-19
    Fighters: 18
    Guns: 17-18
  Defense plan: 11
  Defensive deployment
    Final: **16**
    Initial: **12**
  Defensive problems: 13
  Fighter units, number of: 13
  Guns
    Mix of: 13, 17
    Move: 16
    Number of: 13, 17
    Plan to move: 15
  Pile mattress: **14**, 14, **15**
  Rules of engagement: 13, 17
  V-1s fired against: 11, 18
  V-1s reaching: 19
 Liège, V-1s launched against: 20
V-2: 19, 39, 41
Vampire: 150
VC. See Vietcong
Versailles peace treaty: 23
Vienna, defenses of: 32
Vietcong: 96-97, 101
Vietminh
  Antiaircraft artillery impact on French aircraft,
    Dien Bien Phu: 95-96
Vietnam War: 95-136
  1972 invasion: 115-16
  Aircraft losses
    1962–64: 97
    1961–68, United States: 112
    Geographic area: 112
    Linebacker I: 116, 118
    Linebacker II: 125, 135
  Air tactics
    Anti-SAM: 107-12, 117-18, 122-23, 125-26
    Changed: 126
    United States: 102-3
  Air-to-air combat: 102, 129
  Air war
    United States unprepared: 126
  Antiaircraft artillery
    Direct attack: 126
    Major obstacle: 102, 126
    Underestimated: 101-2
  Antiradiation missiles
    Shrike: **110**, 110-11, **111**, 123, 125
      Effectiveness: 110
    Standard: 110-11, 123, **124**, 125
  Claims
    Surface-to-air missiles, 1965–68: 107
  Dien Bien Phu: 95-96
  Dumb munitions: 101
  Electronic countermeasures: 101, 107-8, 112, 121-23
    B-52: 121-22
    Impact on losses: 127
    Pods: 111
      Impact on operations: 112
      Problems: 132
  F-105 losses: 128
  French involvement: 95-96
  Helicopter losses
    United States: 113-15, 131
  Iron Hand: 109, 111, 118
  Lam Son 719: 113
  Linebacker I: 116-19
    Aircraft losses: 116, 118
    Ratio of support aircraft: 119
    Totals: 118
  Linebacker II: 107, 119-27, 135
    Aircraft losses: 119-27, 135
    Air tactics, United States: 120-21, 125, 127
    B-52D and B-52G: 121, 133
    Electronic countermeasures: 122-23
    Lack of coordination: 122
    MiGs nullified: 125
    "Press on" tactics: 122-23, 133-34
    SAC over-control: 122
    Success: 127, 134
    Tonnage dropped: 124
  LORAN: 117, 124
  Military restrictions on air war: 99-101
  Na San, Vietnam: 95

North Vietnam
  Air defenses: 101-2, 127
  Guns: **98**, 102
  Surface-to-air missiles, 1965–68: **104**, **105**, **106**, 107-8, 110, 112, **115**, 115-16, 122, 125, 127
Operation Bolo: 102
Political restrictions on air war: 99, 103
Rolling Thunder: 99-112
  Objectives: 99
SA-2: **104**, **105**, **106**, 107-8, 110, 112, 116, 122, 125
SA-7: **115**, 115-16
Smart bombs: 117
Surface-to-air missiles
  Firings: 107, 116, **124**
  Impact on operations: 127
  United States Navy shoots down Vietnamese aircraft: 136
Tet offensive: 112
Weather: 100
Wild Weasel: 109, **111**, 111, 118, 123
von Braun, Wernher: 37
von Richthofen, Manfred: 68
Vulcan (British bomber): 151, **152**, 153, 155
Vulcan (United States gun): 146n

Wasserfall: 39-41, **42**, 104
Watson-Watt, Robert A.: 15
Welch, Larry D. (quote): 166
Wesel: 46
Western Electric: 83
White, Thomas D.: 81
Wild Weasel: 109, **111**, 111, 118, 123
Window: 43. See also chaff
Wizard: 89
Wolf: 147
Women gunners, Great Britain: 6, **7**
World War I: 1-2, **2**, **3**
World War II: 5-6, 8-10, 17-19, 21-23, 29-32, 43-46, 51-52, 54, 54n, 58, 67, 177-79
  Lessons: 57

Zemke, Hubert: 68
ZSU-23: 164
ZSU-23-4: 135, 140-42, **142**

AU PRESS